2021-2349

United States Court of Appeals
For the Federal Circuit

INFERNAL TECHNOLOGY, LLC, TERMINAL REALITY, INC.,

Appellants

v.

ACTIVISION BLIZZARD INC.,

Appellee

2021-2349

Appeal from the United States District Court for the Northern District of Texas in Case No. 3:18-cv-01397-M, Judge Barbara M. G. Lynn

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APPELLANTS' OPENING BRIEF
(ORAL ARGUMENT REQUESTED)

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December 03, 2021

CERTIFICATE OF INTEREST

Counsel for Plaintiffs – Appellants certify under Federal Circuit Rule 47.4 that the following information is accurate and complete to the best of their knowledge:

1. Represented Entities. Fed. Cir. R. 47.4(a)(1). Provide the full names of all entities represented by undersigned counsel in this case.

Infernal Technology, LLC
Terminal Reality, Inc.

2. Real Party in Interest. Fed. Cir. R. 47.4 (a)(2). Provide the full names of all real parties in interest for the entities. Do not list the real parties if they are the same as the entities.

None/Not Applicable

3. Parent Corporations and Stockholders. Fed. Cir. R. 47.4(a)(3). Provide the full names of all parent corporations for the entities and all publicly held companies that own 10% or more stock in the entities.

None/Not Applicable

4. Legal Representatives. List all law firms, partners, and associates that (a) appeared for the entities in the originating court or agency or (b) are expected to appear in this court for the entities. Fed. Cir. R. 47.4 (a)(4).

Eric W. Buether
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Daniel F. Olejko (withdrawn and no longer a legal representative of Appellants)

5. Related Cases. Provide the same titles and numbers of any case known to be pending in this court or any other court or agency that will directly affect or be directly affected by this court's decision in the pending appeal. Do not include the originating case number(s) for this case. Fed. Cir. R. 47.4(a)(5). See also Fed. Cir. R. 47.5(b).

Pursuant to Federal Circuit Rule 47.4(a)(5), Plaintiffs – Appellants list the following pending cases:

- Infernal Technology, LLC v. Sony Interactive Entertainment America, LLC, No. 2:19-cv-00248-JRG (E.D. Tex.)
- Infernal Technology, LLC v. Epic Games, Inc., No. 5:19-CV-00516-BR (E.D.N.C.)
- Infernal Technology, LLC v. Take-Two Interactive Software, Inc., No. 1:19-cv-09350-JGK-KNF (S.D.N.Y.)
- Infernal Technology, LLC v. Ubisoft, Inc., No. 5:20-CV-00223-D (E.D.N.C.)

6. Organizational Victims and Bankruptcy Cases. Provide any information required under Fed. R. App. R. 26.1(b) (organizational victims in criminal cases) and 26.1(c) (bankruptcy case debtors and trustees). Fed. Cir. R. 47.4(a)(6).

None/Not Applicable

December 03, 2021

/s/ Eric W. Buether
Eric W. Buether

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Parties	
Activision	Appellee Activision Blizzard, Inc.
Infernal	Appellant Infernal Technology, LLC
TRI	Appellant Terminal Reality, Inc.
Plaintiffs	Appellants Infernal Technology LLC and Terminal Reality, Inc.
Patents-in-Suit	
`822 Patent	U.S. Patent No. 6,362,822
`488 Patent	U.S. Patent No. 7,061,488
Randel Patents	The `822 and `488 Patents
Defined Terms	
Appx0001-4968	Joint Appendix pages
Judge Lynn/District Court	The district court presiding over the present action
Summary Judgment Order	Order Granting Defendant's Motion for Summary Judgment of Noninfringement and Defendant's Motion to Exclude the Opinions of Plaintiffs' Damages Expert Lance Gunderson

STATEMENT OF RELATED CASES

Pursuant to Federal Circuit Rule 47.5, Appellants state as follows:

I am aware of four cases that are related:

- Infernal Technology, LLC v. Sony Interactive Entertainment America, LLC, No. 2:19-cv-00248-JRG (E.D. Tex.)
- Infernal Technology, LLC v. Epic Games, Inc., No. 5:19-CV-00516-BR (E.D.N.C.)
- Infernal Technology, LLC v. Take-Two Interactive Software, Inc., No. 1:19-cv-09350-JGK-KNF (S.D.N.Y.)
- Infernal Tech., LLC v. Ubisoft, Inc., No. 5:20-CV-00223 (E.D.N.C.)

This statement is guided by the statement in the Practice Notes to Rule 47.5 that "[c]ases are not 'related' within the meaning of Federal Circuit Rule 47.4(a)(5) and 47.5(b) simply because they involve the same general legal issue, for example, an issue as to the correct construction of a statute or regulation."

December 3, 2021

/s/ Eric W. Buether
Eric W. Buether

STATEMENT OF JURISDICTION

The District Court entered a judgment granting Activision's Motion for Summary Judgment of Non-Infringement on September 16, 2021. This judgment is a final decision that disposes of all of the Plaintiffs' claims. Activision did not have any pending counterclaims. Plaintiffs timely filed their Notice of Appeal with respect to the judgment on September 19, 2021. This Court has appellate jurisdiction under 28 U.S.C. § 1295(a)(1).

STATEMENT OF THE ISSUES

1. Whether the District Court committed reversible error in granting Activision's motion for summary judgment of noninfringement on the ground that Plaintiffs had no evidence proving the "combining of observer data" step of the claims using a construction of "observer data" materially different from the District Court's construction of the term.

2. Whether the District Court committed reversible error in granting Activision's motion for summary judgment of noninfringement on the ground that Plaintiffs had no evidence that the accused video games perform the comparing, storing and combining steps of the claims in the required sequence based upon a construction of the "sequence of steps" requirement materially different from the District Court's construction of the requirement

3. Whether the District Court committed reversible error in excluding the expert report of Plaintiffs' damages expert because the District Court did not agree that Plaintiffs' evidence showed a nexus between Activision's infringement of the asserted method claims through testing and demonstration of the accused video games and its sales of those games.

THE APPLICABLE STANDARDS OF REVIEW

1. The Federal Circuit reviews a district court's grant of summary judgment de novo. *Revolution Eyewear, Inc. v. Aspex Eyewear, Inc.,* 563 F.3d 1358, 1365 (Fed. Cir. 2009). Summary judgment is appropriate where there is no genuine issue of material fact and the moving party is entitled to judgment as a matter of law. Fed. R. Civ. P. 56(c); *AquaTex Indus., Inc. v. Techniche Solutions,* 419 F.3d 1374, 1379 (Fed. Cir. 2005). Thus, summary judgment may be granted when no "reasonable jury could return a verdict for the nonmoving party." *Anderson v. Liberty Lobby, Inc.,* 477 U.S. 242, 248, 106 S. Ct. 2505, 91 L. Ed. 2d 202 (1986).

2. Regarding the District Court's decision to exclude the expert report of Plaintiffs' damages expert, for issues not unique to patent law, the Federal Circuit applies the law of the regional circuit. *Info-Hold, Inc. v. Muzak LLC*, 783 F.3d 1365, 1371 (Fed. Cir. 2015); *Allergan, Inc. v. Athena Cosmetics, Inc.,* 738 F.3d 1350, 1354 (Fed. Cir. 2013). The Fifth Circuit reviews the admission or exclusion of expert testimony for abuse of discretion. *Bocanegra v. Vicmar Servs., Inc.*, 320 F.3d 581, 584 (5th Cir. 2003). "A trial court abuses its discretion when its ruling is based on an erroneous view of the law or a clearly erroneous assessment of the evidence." *Id. See also Cooter & Gell v. Hartmarx Corp.,* 496 U.S. 384, 405, 110 S. Ct. 2447, 110 L. Ed. 2d 359 (1990) ("A district court would necessarily abuse its discretion if it

based its ruling on an erroneous view of the law or on a clearly erroneous assessment of the evidence.")

STATEMENT OF THE CASE

A. Preliminary statement

The District Court's errors in granting Activision's motion for summary judgment of noninfringement stem from two instances of the lower court's failure to properly apply her own constructions of claim language – claim constructions to which both parties agreed. The meaning and impact of these claim constructions on the issues of the infringement on appeal are clear

First, Judge Lynn failed to apply her claim construction construing the term "observer data" as "data representing **at least** the color of objects . . . ." Judge Lynn acknowledged that this construction meant that "observer data includes, but is not limited to, color data, and may include additional data depending on Plaintiffs' infringement theory and contentions." Notwithstanding this, Judge Lynn ruled that the term "said observer data" in the "combining" step of each of the asserted claims, required the combining of **all** the provided observer data, rather than "data representing **at least** the color of objects," as specified in her construction of the term. Judge Lynn incorrectly granted summary judgment of noninfringement because Plaintiffs did not show that the accused games combined **all** observer data with light accumulation buffer data – something not required by the definition of

"observer data." It is undisputed that Plaintiffs submitted evidence of the accused games combining data representing at least the color of objects – meeting the construction of "observer data."

Second, Judge Lynn also improperly applied the "sequence of steps" construction – also agreed to by the parties – requiring that the steps of comparing and storing specific data for a "plurality of light sources" be completed before beginning "the combining step." Judge Lynn wrongly ruled that, if an accused game began to perform **any** form of combining for **any** light source, then the "sequence of steps" requirement cannot be satisfied. The error in this ruling is that the "sequence of steps" requirement only applies to a "plurality of light sources" and to only the specific combining step described in the asserted claims involving "observer data," as construed. Judge Lynn erroneously ruled that **any** "combining" of **any** data begun prior to the completion of any comparing and storing data for any **light** source precludes a showing of infringement. Activision did not show that, as a matter of law, Plaintiffs cannot prove that, "for a plurality of light sources," the accused games complete the comparing and storing steps before beginning the combining step involving "observer data" including at least color data, and Plaintiffs submitted evidence of the accused games doing precisely that.

Finally, Judge Lynn erroneously excluded the expert report of Plaintiffs' damages expert on the ground that the report failed to show that there was a nexus

between Activision's sales of the accused games and Activision's alleged infringement of the asserted method claims through internal testing of those games. Judge Lynn acknowledged that Plaintiffs submitted substantial evidence on the nexus issue but excluded the expert report because she "disagrees with this evidence." This conclusion was erroneous because Judge Lynn weighed the nexus evidence and made her own determination regarding whether a nexus existed. Judge Lynn also incorrectly ruled that the Plaintiffs' expert report was required to contain opinions about the causal link between Activision's infringement of method claims through testing of the accused games and its sales of those games. This ruling is contrary to a long line of decisions holding that a damages expert need not opine on the issue of causation, and disregarded the evidence of the nexus submitted by Plaintiffs and identified by the damages expert in his report on the issue of damages.

B. Background

Plaintiff Terminal Reality is a developer of video games and video game engine technology. Appx0101-0102 (Complaint at 1-2). Mark Randel, the inventor of the patents-in-suit (the "Randel Patents"), formed Terminal Reality in 1994. *Id*. Plaintiff Infernal Technology is the exclusive licensee of the Randel Patents and, since 2014, has had the exclusive right to sue for and recover all past, present and future damages for infringement of the Randel Patents. *Id*.

Defendant Activision Blizzard is engaged in the business of developing, testing, publishing, distributing, and selling video games. At the heart of these video games is software called a "game engine" which is used to develop and run the operations of the video game. Appx0102-0103 (Complaint at 2-3); Appx0125-0126 (Answer at 2-3).

In 1999, Randel applied for what became the '822 Patent. Appx0029 ('822 Patent at 1). In 2001, Randel applied for what became the '488 Patent. Appx0045 ('488 Patent at 1). The '488 Patent was a continuation of the '822 Patent and shares the same specification.[1]

The Randel Patents are entitled "Lighting and Shadowing Methods and Arrangements for Use in Computer Graphic Simulations." These patents "relate[] to computer graphics and, more particularly, to improved methods and arrangements for use in rendering lighting and shadows in computer graphic simulations, such as, for example, interactive computer graphics simulations of multidimensional objects." Appx0029 ('822 Patent, 1:6-11).

The '822 Patent provides improved shadow rendering methods and arrangements that "support real time interactive graphics on conventional PCs and the like, and allow for multiple light sources to be modeled in a more efficient and realistic manner." *Id.* at 2:65-3:3. The specification explains that, according to the

[1] All citations in this brief are to the '822 Patent.

claimed invention, this improved rendering is accomplished by operating on rendered pixels in 2D space, which significantly minimizes the number of calculations required to produce proper lighting and shadowing in each frame by initially rendering a full, 2D image of the scene from the perspective of the camera (or the "observer"). *Id*. at 8:39–41. This 2D data is often referred to as "observer data." *See id.* Appx0029 ('822 Patent, Figure 2, depicting a 3D computer graphics screen from the "observer's perspective").

Also, "by using [a] light accumulation buffer, . . . a more realistic shadow rendering can occur, because pixels are accumulatively lighted, rather than accumulatively darkened as in past interactive real time shadow rendering algorithms." *Id.* at Appx0029 ('822 Patent, 7:49-53). This light accumulation buffer accumulates, for each pixel to be displayed, the contribution from each light illuminating that pixel. The pixels to be displayed were determined by rendering the scene from the perspective of the camera before performing the lighting and shadowing. *Id.* at 8:39-44. The resultant accumulated illumination is combined with characteristics of the pixel in question to determine the resultant color for that pixel. *Id.* at 8:56-9:22. By utilizing the light accumulation buffer, the lighting for multiple lights "provides realistic lighting and shadow rendering while also being computationally efficient." *Id.* at 9:24-26. By first rendering the scene from the camera's perspective and making use of the separate light accumulation buffer,

objects in the scene need only be rendered once from the perspective of the camera (observer). The invention of the Randel Patents efficiently renders lighting and shadowing by simply iterating through a 2D array of pixels. The process ensures realistic shadow rendering regardless of the number of light sources, because the light is accumulated for a plurality of lights and applied only once to the rendered camera image.

C. Relevant Procedural History

Plaintiffs filed this lawsuit on May 31, 2018, alleging that certain video games and the video game engines that run those games that Activision developed, tested, published, distributed, and sold infringe one or more claims of the Randel Patents. Appx0102-0103 (Complaint at 2-3).

Judge Lynn held a claim construction hearing on August 16, 2019, and issued a claim construction order on September 6, 2019. Appx1236 (Claim Construction Order at 1). The parties served expert reports and completed expert discovery in June, 2021.

In May 2021, the parties submitted motions for summary judgment and motions to exclude expert witnesses. Among the motions filed by Activision was a Motion for Summary Judgment of Invalidity and Noninfringement. Appx1302-2399. Infernal filed its response to this motion on June 11, 2021, Appx2979-4074, and Activision filed its reply brief on July 2, 2021. Appx4256-4287. Activision also filed a Motion

to Exclude the Opinions of Plaintiffs' Damages Expert Lance Gunderson (the "Activision Motion to Exclude Gunderson"). Appx4075-4255. Plaintiffs filed their response to this motion on July 8, 2021. Appx4288-4808. Activision filed its reply brief on July 21, 2021. Appx4818-4887.

Judge Lynn held a hearing on the pending dispositive motions and motions to strike filed by the parties on August 16, 2021. Following the August 16, 2021 hearing on the parties' dispositive motions and motions to strike, Plaintiffs withdrew their claims of infringement for Claims 2-4 and 7 of the '822 Patent, and Claims 6, 28, and 29 of the '488 Patent. Appx0003 (Summary Judgment Order at 3). The remaining asserted claims were Claim 1 of the `822 Patent and Claim 1 and 27 of the `488 Patent.

On September 16, 2021, Judge Lynn entered a Summary Judgment Order granting Activision's Motion for Summary Judgment of Noninfringement and Activision's Motion to Exclude Gunderson. Appx0002-0028 (Summary Judgment Order). In the Summary Judgment Order, Judge Lynn ruled that "summary judgment of noninfringement is warranted for all asserted claims because the accused games do not satisfy the 'combining' limitation, and because the accused games do not perform the claimed method in the sequence required by the Court's claim construction. Because these decisions are case dispositive, the Court does not reach the other grounds for summary judgment raised by Activision." *Id*. at 5-6. In

granting Activision's Motion to Exclude Gunderson, Judge Lynn stated that, "[b]ecause the Court concludes that the sole damages theory put forth by Gunderson is insufficiently tied to the facts of the case, the Court grants Activision's motion to strike Gunderson's report. The Court denies the remainder of the motion as moot in light of the Court's decision to grant of summary judgment of noninfringement." *Id.* at 21.

SUMMARY OF ARGUMENT

Judge Lynn committed reversible error when she granted Activision's motion for summary judgment of noninfringement. The District Court's error consisted of two erroneous applications of its own claim constructions.

First, each of the asserted claims require the claimed method or apparatus to, *inter alia*, (1) provide "observer data" and "lighting data"; (2) then, for a "plurality" of light sources, "compare" at least a portion of said observer data with at least a portion of said lighting data," and "store" at least a portion of the resulting light image data in a "light accumulation buffer"; and then (3) "combine" at least a portion of the data in the light accumulation buffer with "said observer data." The parties agreed, and Judge Lynn ordered, that the term "observer data," as used in the asserted claims, meant "data representing **at least** the color of objects . . . ." Appx1246 (Claim construction Order at 11) (emphasis added).

Activision argued that the "said observer data" referred to in the "combining" step had to include **all** "observer data" provided in the previous "providing" step, and that Activision's accused video games did not "combine" **all** of the observer data provided in that step. Plaintiffs argued that this interpretation of the claim language, as construed, was wrong because it was contrary to the parties' agreed construction, adopted by Judge Lynn, which defined "observer data" as requiring only "data representing **at least** the color of objects." Plaintiffs submitted evidence showing that Activision's accused video games did "provide" observer data representing at least the color of objects and then combined such data "representing at least the color of objects" in the "combining" step, in accordance with the applicable claim construction.

Judge Lynn accepted Activision's argument and erroneously ruled that the term "said observer data" in the "combining" step required the accused video games combine **all** observer data provided in the previous "providing" step. Judge Lynn erred by ruling that summary judgment of noninfringement was appropriate because Activision's accused games did not combine **all** observer data provided in the previous "providing" step is contrary to the construction of the term as requiring only at least color data.

Second, Judge Lynn adopted the parties' claim construction providing that, with regard to the steps of comparing, storing and combining, the "comparing and

storing steps are completed before beginning the combining step." Appx1246 (Claim construction Order at 11). Judge Lynn wrongly concluded that this "sequence of steps" requirement applied to **each and every light source** when the claim language and construction of that language required the sequence for **"a plurality of light sources."** This led Judge Lynn to erroneously rule that Activision could not infringe the asserted claims as a matter of law because there were instances when the sequence was allegedly not performed for a single light source.

In addition, Judge Lynn erroneously ruled that Activision did not infringe as a matter of law because there were instances when its accused games began an undefined "combining" of data before completing any comparing and storing steps. This ruling was contrary to the "sequence of steps" requirement that it must be the combining step as claimed -- involving the combining of **observer data comprising at least color data** – that could not begin before completing the associated comparing and storing steps.

Judge Lynn improperly dismissed Plaintiffs' argument that the asserted claims were open ended and, therefore, did not exclude additional, unrecited elements or method steps performed in an unspecified order. Plaintiffs submitted evidence showing that Activision's accused video games performed **the** comparing, storing and combining steps in the specified order for a "plurality of light sources."

Nevertheless, Judge Lynn erroneously granted Activision's motion for summary judgment of noninfringement.

Finally, Activision, in conjunction with filing its motion for summary judgment of noninfringement, filed a motion to exclude the expert report of Plaintiffs' damages expert – Lance Gunderson. Activision's argument in support of this motion was based on the fact that Gunderson used the revenue Activision derived from the sales of the accused video games to measure the reasonable royalty damages for Activision's infringement of the asserted method claims through its extensive internal testing and public demonstration of the accused video games. Plaintiffs contended that the evidence in the record showed a substantial connection between this infringing testing and demonstration of the accused video games and the sales of those games.

Judge Lynn granted Activision's motion and excluded the Gunderson expert report in its entirety based on her conclusion that the Gunderson report "does not show a nexus between sales of the accused game and performance of the asserted method claims." Judge Lynn acknowledged that, in accordance of with this Court's decision in the *Carnegie Mellon* case and other pertinent decisions, "in some instances, it may be appropriate to base damages for internal use of a claimed method on product sales." Judge Lynn, however, abused her discretion when she incorrectly ruled that, as a matter of law, the Gunderson expert report itself had to include an

opinion "showing a nexus between sales of the accused game and performance of the asserted method claims." Judge Lynn did not address the long line of decisions holding that a damages expert does not have to offer an opinion on the issue of causation of damages. Such causation or nexus can be shown through other sources of evidence.

Furthermore, Plaintiffs did submit substantial evidence showing such a nexus. Thus, Judge Lynn's statement that there was "no evidence" in the record of a nexus between Activision's testing and demonstration of the accused video games and its sales of those games was a clearly erroneous assessment of the evidence.

In addition, Judge Lynn inappropriately weighed the strength of Plaintiffs' nexus evidence when she concluded that "[t]his evidence does not show a nexus or connection between Activision's performance of the claimed method and sales." This was a determination for the jury to make, not the trial court in the context of a *Daubert* motion.

Judge Lynn also abused her discretion by ruling that Gunderson's damages report was legally flawed in its entirety because "Gunderson presents a unitary damages theory and does not indicate which portion of his proposed royalty is based on alleged infringement of the method claims versus the asserted apparatus claim . . . ." Judge Lynn did not explain her ruling further and did not cite or discuss any authority supporting the ruling – most likely because there is none.

Gunderson's methodology for measuring the reasonable royalty for Activision's infringement of the asserted apparatus claim for its infringing sales of the accused video games is the same as his methodology for measuring the reasonable royalty for Activision's infringement of the asserted method claims for its infringing testing and demonstration of those games – the value to Activision from using the patented technology. In both cases, Gunderson's expert damages report provides the same estimate. The value to Activision would be the revenue Activision receives from the sales of those games. In addition, the Gunderson report provides details regarding Activision's sales of the accused video games that would enable the jury to award a different amount of reasonable royalty damages, if it determined that was warranted by the evidence for either Activision's infringement of the apparatus or the method claims.

ARGUMENT

A. The District Court Committed Reversible Error By Granting Summary Judgment of Noninfringement

The District Court committed reversible error when it granted Activation's Motion for Summary Judgment of Noninfringement. In granting this motion, the District Court misapplied its own construction of two claim terms that were agreed to by the parties.

1. The Summary Judgment Standard

Summary judgment is proper under Rule 56(a) of the Federal Rules of Civil Procedure "if the movant shows that there is no genuine dispute as to any material fact and the movant is entitled to judgment as a matter of law." Fed. R. Civ. P. 56(a). The trial court "must resolve all reasonable doubts in favor of the party opposing the motion for summary judgment." *Casey Enters., Inc. v. Am. Hardware Mut. Ins. Co.*, 655 F.2d 598, 602 (5th Cir. 1981).

The party seeking summary judgment bears the initial burden of informing the Court of its motion and identifying "depositions, documents, electronically stored information, affidavits or declarations, stipulations (including those made for purposes of the motion only), admissions, interrogatory answers, or other materials" that demonstrate the absence of a genuine issue of material fact. Fed. R. Civ. P. 56(c)(1)(A); *Celotex*, 477 U.S. at 323. If the movant bears the burden of proof on a claim or defense for which it is moving for summary judgment, it must

come forward with evidence that establishes "beyond peradventure *all* of the essential elements of the claim or defense." *Fontenot v. Upjohn Co.*, 780 F.2d 1190, 1194 (5th Cir. 1986).

Once the movant has carried its burden, the nonmovant must "respond to the motion for summary judgment by setting forth particular facts indicating there is a genuine issue for trial." *Byers v. Dallas Morning News, Inc.*, 209 F.3d 419, 424 (5th Cir. 2000) (citing *Anderson*, 477 U.S. at 248–49). A nonmovant must present affirmative evidence to defeat a properly supported motion for summary judgment. *Anderson*, 477 U.S. at 257. The Court must consider all the evidence but "refrain from making any credibility determinations or weighing the evidence." *Turner v. Baylor Richardson Med. Ctr.*, 476 F.3d 337, 343 (5th Cir. 2007).

This Court has reversed orders by district courts granting summary judgment of noninfringement on numerous occasions. *See*, e.g., *Xerox Corp. v. 3Com Corp.,* 267 F.3d 1361, 1367–69, 60 U.S.P.Q.2d 1526 (Fed. Cir. 2001) (reversing summary judgment of no infringement because, although district court correctly construed claim, it incorrectly determined that accused product could not meet the claim limitations); *Ethicon Endo-Surgery, Inc. v. Covidien, Inc.*, 796 F.3d 1312, 1325-27 (Fed. Cir. 2015) (vacating summary judgment of noninfringement and remanding since there were issues of fact on whether the accused product met the limitation).

B. The District Court Committed Reversible Error By Granting Summary Judgment of Noninfringement Concerning the "Combining" Step Based Upon an Erroneous Application of the Court's Own Construction of "Observer Data"

1. The District Court's Erred in Ruling that "Said Observer Data" in the Combining Step Means All Provided Observer Data Rather than Simply "Data Representing At Least the Color of Objects," as Specified by the Court's Claim Construction

The District Court's Summary Judgment Order states that "Activision argued that the accused games do not practice 'combining at least a portion of said light accumulation buffer with said observer data,' which is a limitation present in all asserted claims." Appx0007 (Summary Judgment Order at 6).[2]

Judge Lynn noted that "Activision's argument is two-fold." *Id*. "First," Judge Lynn observed that, "based on the plain and ordinary meaning of the claim language, Activision contends that 'said observer data' used in the 'combining' step (element 1(d)) refers to the same observer data from the 'providing' step (element 1(a))." "Put differently," Judge Lynn stated, "Activision argues that the observer

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[2] The District Court also stated that, "[b]ecause each asserted claim contains identical claim limitations requiring (a) 'providing observer data . . .', (b) 'for each of said plurality of light sources, comparing at least a portion of said observer data . . . ,' and (d) 'combining at least a portion of said light accumulation buffer with said observer data,' the Court's analysis regarding elements 1(a), 1(c), and 1(d) in Claim 1 of the '822 patent applies equally to all asserted claims. The Court at times refers to these elements as the 'providing,' 'comparing,' and 'combining,' steps, respectively." Appx0007 (Summary Judgment Order at 6). Plaintiffs will do the same.

data provided in 1(a) must be the same as what is combined in 1(d), and that the term 'at least a portion of said observer data' in the 'comparing' step (element 1(c)) refers to a subset of the observer data provided in 1(a)." *Id*.

"Second," Judge Lynn observed, "Activision argues, based on this interpretation, that Plaintiffs' evidence of infringement does not satisfy the combining step, because the observer data Plaintiffs' expert Dr. Aliaga identifies in the providing step consists of depth buffer and geometry buffer data, while the observer data Plaintiffs' expert identifies in the combining step consists of only a subset of geometry buffer data, namely albedo, diffuse, or other color data, depending on the accused game." In addition, Judge Lynn noted "that Activision argues that Plaintiffs identify two different subsets of observer data for the comparing and combining steps, and thus cannot argue that the 'said observer data' limitation in the combining step refers back to the 'at least a portion of said observer data' limitation in the comparing step." Appx0008 (Summary Judgment Order at 7).

Judge Lynn accepted these arguments, and concluded that summary judgment of noninfringement is warranted for all asserted claims because the accused games do not satisfy the 'combining' limitation." Appx0006-0007 (Summary Judgment Order at 6-7). Specifically, Judge Lynn rejected Plaintiffs' argument "that the asserted claims do not require that 'all' the observer data from the providing step be

used in the combining step," and agreed with Activision that "the combining step requires 'all' observer data provided in the providing step" be used in the "combining" step, and not "some subset of the data." *Id*.[3]

Based upon this misunderstanding of the claim terms, as construed, Judge Lynn concluded that Activision was entitled to summary judgment of noninfringement because "Plaintiffs have failed to show a genuine issue of material fact that all elements of the asserted claims are met. Plaintiffs do not dispute that Dr. Aliaga (Plaintiffs' technical expert) identifies 'said observer data' in element 1(d) as constituting only a subset of the observer data provided in 1(a), . . ." Appx0007 (Summary Judgment Order at 16). Judge Lynn wrongly stated that this was "contrary to the plain and ordinary meaning of 'said observer data.'" *Id*. In fact, it was entirely consistent with Judge Lynn's construction of the claim language.

Judge Lynn, therefore, erred in reaching her summary judgment decision on the combining step issue by misapplying her own explicit construction of the term

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[3] As Activision asserted in its motion for summary judgment of noninfringement, "according to Plaintiffs' own infringement contentions and expert reports, the accused games do not combine all of the provided observer data with what Plaintiffs contend is the light accumulation buffer. Rather, Plaintiffs' own contentions and experts admit that *only a portion* of the provided observer data is combined with a portion of the alleged light accumulation buffer. This is improper as a matter of law, as the plain language of the claims requires that all 'said observer data' be combined, not merely a portion thereof." Appx1769 (Brief in Support of Defendant's Motion for Summary Judgment at 1) (emphasis in the original).

"observer data." Judge Lynn's construction of the term was clear: "observer data of a simulated multidimensional scene" means "data representing **at least** the color of objects in a simulated multidimensional scene as viewed from an observer's perspective." Appx0005 (Summary Judgment Order at 4); Appx1246 (Claim Construction Order at 11) (emphasis added). Judge Lynn's summary judgment decision based upon her misinterpretation of the term "observer data" as requiring "all" of the observer data provided by the accused games is completely inconsistent with Judge Lynn's construction of the term as simply requiring data representing "at least" color data. Because Judge Lynn's summary judgment decision was based upon this erroneous application of the "observer data" term, this Court should reverse that decision.

2. The District Court Acknowledged that Its Construction of "Observer Data" as "At Least" Color Data is Open-Ended

The District Court acknowledged that the term "at least" used in the construction of "observer data" is an open-ended term that can include observer data other than color data, but must include only color data. As Judge Lynn observed:

> In addition, during *Markman*, the parties agreed that "observer data of a simulated multidimensional scene" means "data representing *at least* the color of objects in a simulated multidimensional scene as viewed from an observer's perspective." *Markman* Order, at 39 (emphasis added). **Thus, observer data includes, but is not limited to, color data, and may include additional data depending on Plaintiffs' infringement theory and contentions.**

Appx0014 (Summary Judgment Order at 13) (emphasis added).

Neither Judge Lynn nor Activision has questioned that the well-established meaning of the term "at least" means one or more of the items in question. *See SanDisk Corp. v. Kingston Tech. Co.*, 695 F.3d 1348, 1360–61 (Fed. Cir. 2012), *Biagro W. Sales, Inc. v. Grow More, Inc.,* 423 F.3d 1296, 1304 (Fed. Cir. 2005); *Rhine v. Casio, Inc.*, 183 F.3d 1342, 1345, 51 U.S.P.Q.2d 1377 (Fed. Cir. 1999).

Thus, for example, "observer data" under the "providing" step of step 1(a) could encompass depth data so long as it also encompassed "color data." The former is permissive, but the latter, and only the latter, is required. It is proper to use color data for the combining step of 1(d), because color data satisfies the definition of "observer data," which only requires "data representing **at least** the color of objects." It is also appropriate to use depth data, for the comparing step of 1(c) because the step only requires use of **a portion** of "said observer data," i.e. **a portion** of the data provided in step 1(a) which included "data representing **at least** the color of objects . . . ."

3. The District Court Improperly Focused on the Meaning of "Said" and Not Its Construction of "Observer Data"

Judge Lynn erred by failing to apply the "at least color data" construction for "observer data" when determining whether, under step 1(d), there was a disputed fact issue concerning whether Activision's accused games satisfied the "combining" step of the claim. Judge Lynn focused on the meaning of the term "said" in the

phrase "said observer data" used in that step, but failed to apply the "at least color data" construction of the term "observer data."

In this appeal, Plaintiffs do not question the applicability of the "antecedent basis rule" providing for the term "said" in "said observer data" in the "combining" step of step 1(d) to refer back to the first use of the term "observer data" in the "providing" step of step 1(a). The error committed by Judge Lynn was in failing to complete her analysis of the meaning of "said observer data." Although the term "said" refers one back to the first use of the term "observer data" in the "providing" step, the required analysis does not stop there. One must then ascertain the meaning of "observer data." Judge Lynn already construed that term to mean "at least" color data. It does not mean "all" observer data provided in step 1(a), as Activision contended, and Judge Lynn erroneously ruled. Indeed, Judge Lynn confirmed that she was not modifying her construction of "observer data" as data representing at least color data. Appx0009 (Summary Judgment Order at 8). Thus, Plaintiffs are not contending that the limitation "observer data" has a different meaning in the different places the term is used in Claim 1. The term "observer data" as used throughout Claim 1 means one thing -- "data representing at least the color of objects in a simulated multidimensional scene as viewed from an observer's perspective." It is Judge Lynn that violated the principle that "words in a claim should be interpreted consistently throughout the same claim." Appx0009 (Summary

Judgment Order at 8). In the words of Judge Lynn herself, "absent contrary direction from the specification or the claim language, 'observer data' is presumed to have the same meaning throughout the claim." *Id.*[4] Without any justification, however, the District Court construed "observer data" in the "providing" step as "at least" color data, but "said observer data" in the "combining" step as "all" observer data. This was erroneous.[5]

4. The "Portion of Said Observer Data" Language in Step 1(c) Does Not Compel the Conclusion that "Observer Data" Means "All" Observer Data

Judge Lynn attempted to justify her decision by pointing to the language in the "comparing" step involving "comparing at least a portion of said observer data" with at least a portion of lighting data. Judge Lynn concluded that this "portion of"

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[4] The District Court did not identify anything in the specification indicating that the term "observer data" in the asserted claims should be understood to mean "all" of the observer data provided under step 1(a). *See* Appx0012 (Summary Judgment Order at 11).

[5] Judge Lynn's ruling requiring the "combining" step to involve "all" observer data provided in step 1(a), rather than simply data representing at least color data, is not only contrary to the District Court's claim construction, but it excludes the embodiments of the invention. The embodiments do not disclose "combining" the light accumulation buffer data with anything other than observer color data, even though more than color data is provided in the "providing" step. *See* '822 Patent, 9:4-19. *See also* Appx3003-3005 (Infernal's Resp. to Mot. Summ. J. at 19-21). For example, the disclosed embodiments do not combine the light accumulation buffer data with the observer **depth data** in step 1(d). Doing so would make no sense because they are different data types – one is RGB color data and the other is Z-buffer depth data (i.e., distance data, not RGB color data).

language "suggests that other instances of 'said observer data' are not so qualified, otherwise the qualification in 1(c) would be superfluous." Appx0011 (Summary Judgment Order at 10).

This conclusion, however, ignores the fact that Judge Lynn's construction of "observer data" as only "at least" color data already embodies a significant qualification of the "observer data" limitation – that "observer data" need only comprise "color data," although it can include other data. The "a portion of observer data" language, therefore, does not suggest that the term "observer data" used elsewhere in the claim means "all" observer data. As discussed above, "a portion of observer data" may refer to a portion of the provided "data representing at least the color of objects" – such as the "depth data" portion of provided observer data that includes color data and depth data. *See* discussion, *supra*, at Argument B.2. *See also* Appx0029 (`822 Patent, 3:38-39) ("the observer data includes observed color data and observed depth data"). Put differently, the "portion of observer data" language in the "comparing" step adds a qualification to the scope of the term "observer data" already qualified by the "at least" color data language imposed by the construction of the term itself. The "portion of observer data" referenced in the "comparing" step is a further subset of "data representing at least the color of objects" comprising the definition of "observer data." Thus, the qualification of "observer data" in step 1(c) as "a portion of said observer data" does not conflict

with the District Court's construction of "observer data" as "data representing at least the color of objects," and does not compel the term to include **all** of the observer data provided in step 1(a).

5. Activision Did Not Satisfy Its Initial Burden of Showing an Absence of a Genuine Issue of Material Fact Regarding the Combining Step

In view of Judge Lynn's erroneous application of the "observer data" limitation, Activision did not satisfy its initial burden of identifying evidence in the record that demonstrates the absence of a genuine issue of material fact. Fed. R. Civ. P. 56(c)(1)(A); *Celotex*, 477 U.S. at 323.

As Activision argued, "according to Plaintiffs' own infringement contentions and expert reports, the accused games do not combine all of the provided observer data with what Plaintiffs contend is the light accumulation buffer. Rather, Plaintiffs' own contentions and experts admit that *only a portion* of the provided observer data is combined with a portion of the alleged light accumulation buffer." Appx1775 (Activision's Brief ISO Mot. For Summ. J. at 1).

For the reasons discussed above, however, Plaintiffs did not have to show that the "said observer data" combined in step 1(d) had to be the same observer data (i.e. **all** of the observer data) provided in step 1(a). It only had to be "data representing at least the color of objects in a simulated multidimensional scene as viewed from an observer's perspective" in accordance with the agreed construction of the term.

6. The Record Contains Evidence Showing That Activision's Accused Games Perform the "Combining" Step

The evidence submitted by Activision and Plaintiffs and cited by Judge Lynn in her Summary Judgment Order confirms that Plaintiffs **do** have evidence showing that Activision's accused games satisfy the "combining" step of the accused games.

For example, Judge Lynn acknowledges that "for element 1(a), Activision cites paragraphs from Dr. Aliaga's report indicating that the 'observer data' provided includes 'albedo,' data and depth data." Appx0015 (Summary Judgment Order at 14). It is undisputed that "albedo" data is color data. *Id*. at Appx0017. This data provided, therefore, qualifies as the claimed "observer data" because it is "data representing at least the color of objects." Judge Lynn further acknowledged that "for element 1(d), the combining step, Activision cites Dr. Aliaga's opinions that point to a subset of that observer data, namely "color data, such as 'albedo,' 'diffuse color,' 'specular color,' or other color data derived from a g-buffer for the 'said observer data' in this limitation." *Id*. This data also satisfies the definition of "observer data" because it is "data representing at least the color of objects."[6]

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[6] Regarding the comparing step of step 1(c), the District Court observed that "Plaintiffs' own summary judgment brief cites paragraphs of Dr. Aliaga's report identifying the 'at least a portion of said observer data' used in the 1(c) comparing step as constituting something *other* than albedo data, namely position and depth data." Appx0017 (Summary Judgment Order at 16 n.5). But, as explained above, this is entirely proper. Step 1(c) only requires the use of "at least **a portion** of said observer data," and depth data is portion of the data provided in step 1(a) that

Thus, in accordance with the proper application of the claim language, as construed, not only did Activision fail to sustain its initial burden to demonstrate the absence of a genuine issue of material fact, the evidence submitted by Plaintiffs showed the existence of such a disputed genuine issue of material fact. Plaintiffs have satisfied their burden to show that, even if the Activision had carried its burden, "particular facts indicating there is a genuine issue for trial." *Byers*, 209 F.3d at 424 (citing *Anderson*, 477 U.S. at 248–49).

C. The District Court Committed Reversible Error By Granting Summary Judgment of Noninfringement Based Upon Activision's Contention that Its Accused Games Cannot Perform the Required Steps in the Specified Sequence

The District Court offered a second reason why it granted summary judgment of noninfringement – that "the accused games do not perform the claimed steps in order." Appx0018 (Summary Judgment Order at 17. Judge Lynn correctly observed that "the asserted claims each recite steps requiring, for each of a plurality of light sources, comparing light image data and storing it in a light accumulation buffer (*e.g.*, element 1(c)), and combining at least a portion of the light accumulation buffer with observer data (*e.g.*, element 1(d))." *Id*. Judge Lynn also noted that, "[u]nder the Court's agreed construction, "the comparing and storing steps are completed before beginning the combining step." *Id*. Judge Lynn's application of this claim

includes the albedo color data, which makes it "data representing **at least** the color of objects."

language and claim construction to the facts of this case, however, was fraught with error.[7]

1. The District Court's "Sequence of Steps" Construction Applied Only to "a Plurality" of Light Sources – Not Every Light Source Illuminating the Scene

As an initial matter, it bears emphasis that, as Judge Lynn correctly noted, the required sequence of steps applies only to "a plurality of light sources," and not every light source. *See, e.g.,* `822 Patent, Claim 1, element 1(b) ("providing lighting data associated with a plurality of light sources"), and element 1(c) ("for each of said plurality of light sources . . ." "comparing" and "storing."). It is well-established that "a plurality of" means "at least two of." *SIMO Holdings Inc. v. H.K. uCloudlink Network Tech. Ltd.*, 983 F.3d 1367, 1377 (Fed. Cir. 2021).

This is significant because of Judge Lynn's pejorative statement that Plaintiffs cannot "pick and choose which comparing, storing, and combining steps are used to show infringement." Appx0021 (Summary Judgment Order at 20). Although Plaintiffs have not engaged in any improper "picking and choosing," the claim language, including the use of the open-ended transition phrase "comprising," means that infringement may be shown if the accused games perform the recited steps for a plurality of lights in the required sequence, even if the recited steps are not

[7] The parties agreed to this construction, and the District Court adopted it. Appx1246 (Claim Construction Order at 11).

performed for other light sources illuminating a scene, or if additional unrecited steps are performed in a different order."

When a claim uses an "open" transition phrase, its scope may cover devices that employ additional, unrecited elements. *See Moleculon Research Corp. v. CBS, Inc.,* 793 F.2d 1261, 1271, 229 USPQ 805, 812 (Fed.Cir.1986). This Court has consistently held that the word "comprising" is an open transition phrase. *See id.; see also Elkay Mfg. Co. v. Ebco Mfg. Co.,* 192 F.3d 973, 977 (Fed. Cir. 1999). Contrary to Judge Lynn's statement, Plaintiffs are not relying on the word "comprising" as a "'weasel word'" to "'abrogate claim limitations.'" Appx0020 (Summary Judgment Order at 19). Instead, "[c]omprising" is a term of art used in claim language which means that the named elements are essential, but other elements may be added and still form a construct within the scope of the claim. *Genentech, Inc. v. Chiron Corp*., 112 F.3d 495, 501 (Fed. Cir. 1997). Judge Lynn failed to accord the term its established meaning.[8]

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[8] The District Court also wrongly concluded that "[a]t minimum, Plaintiffs have not shown infringement of claim 27 of the '488 patent, which does not use the word 'comprising.'" Appx0021 (Summary Judgment Order at 20). The District Court did not explain its conclusion at all. The asserted claims do not use the term "consisting of" or other language signifying restriction and exclusion or that the claim is otherwise closed-ended. The claim merely requires "a computer-readable medium carrying at least one set of computer instructions configured to cause at least one processor to operatively render simulated shadows in a multi-dimensional simulated scene by performing the steps of . . . ." The claim language does not state that the claimed processor carry computer instructions configured to cause one or more processors to perform **only** the specified steps, and no other steps. Nothing in the specification indicates that this claim should be construed as closed-ended. Activision did not argue that it was entitled to

Therefore, Activision cannot show entitlement to summary judgment of noninfringement by merely pointing to a light source or unidentified group of light sources for which its accused games did not perform the recited steps in the sequence specified in the claim construction. Similarly the fact that Activision has pointed to a light source which it contends performs "a" combining step (as opposed to the claimed combining step) "out of order" does not establish, as a matter of law, that Plaintiffs cannot show that a "plurality of light sources" in an accused game perform the recited steps in the specified sequence.

Judge Lynn, however, erroneously concluded that, if there were evidence that, for **any** light source, the specified sequence of steps was not followed, then Plaintiffs could not prove infringement as a matter of law. As the District Court declared, "because the Court's construction requires that the comparing and storing steps are completed *before beginning* the combining step, the accused games do not infringe the asserted claims because the undisputed evidence shows that combining steps

summary judgment of noninfringement because the claim did not use the "comprising" term or was otherwise closed-ended. It is a basic axiom of patent law that, absent closed-ended claim language, an accused infringer cannot escape an allegation of infringement by showing the accused product contains added elements beyond that which is claimed in the patent at issue. *Genentech, Inc. v. Chiron Corp.*, 112 F.3d 495, 501 (Fed. Cir. 1997). Furthermore, Plaintiffs submitted evidence showing that Activision's accused ames do contain a computer-readable medium carrying computer instructions configured to cause the accused games to perform the recited steps in the specified sequence.

begin before the comparing and storing steps are completed for **each light source**." Appx0019 (Summary Judgment Order at 18) (bolded emphasis added, italics emphasis in the original). As explained above, this ruling by Judge Lynn was erroneous because the relevant claim language and claim constructions do **not** require that the specified sequence of steps be performed "for each light source" in the scene.

2. The District Court's "Sequence of Steps" Claim Construction is Limited to Requiring that the Combining Step Involving "Observer Data" Including "At Least" Color Data Did Not Begin Until the Associated Comparing and Storing Steps are Completed

Judge Lynn also failed to give effect to the claim language "observer data," as she construed that term. The District Court wrongly ruled that "because . . . the accused games perform [unspecified and undefined] combining steps prior to the completion of the comparing and storing steps, the accused games do not infringe the asserted claims." Appx0022 (Summary Judgment Order at 21). Judge Lynn erred because the claim construction providing for the performance of the "sequence of steps" specifies that "the comparing and storing steps are completed before beginning **the** combining step." Appx1246 (Claim Construction Order at 11) (emphasis added). The construction's reference to "the combining step" is not a reference to **any** combining of data, but the recited step of combining light accumulation buffer data with "said observer data." As the Federal Circuit explained

in *Baldwin Graphic Systems, Inc. v. Siebert,* 512 F.3d 1338 (Fed. Cir. 2008), the use of "the" refers back to an earlier use of the claim term.

Here, use of the word "the" refers back to the use of the term "the combining step" in step 1(d), which refers to the combining of "observer data," which necessarily includes at least color data. Combining observer data that does not include at least the color of objects, therefore, is not a recited element of the claims. Thus, the step of combining such "color-less" data is an additional, unrecited step that is irrelevant to the infringement analysis.

Thus, when the District Court ruled that "the comparing and storing steps are completed before beginning of the combining step," that court was referring to **the** combining step of 1(d) involving the combining of the light accumulation buffer with claimed "observer data" necessarily including color data. The combining of just **any** data, even **any observer data** is insufficient to perform the step.

3. Activision Did Not Submit Evidence Showing that, as a Matter of Law, Its Accused Games Began the Claimed Combining Step before Completing the Comparing and Storing Steps for a Plurality of Light Sources

Once again, Judge Lynn erred by failing to adhere to her own claim construction for the term "observer data." Judge Lynn ruled that "Activision argues that summary judgment of noninfringement is appropriate because the accused games perform [unspecified and undefined] combining steps before [unspecified and undefined] comparing and storing steps are completed [for unspecified light

sources], and thus the steps are not performed in the order required by the Court's claim construction." Appx0018 (Summary Judgment Order at 17). Judge Lynn accepted this Activision argument and held that "the accused games perform [unspecified and undefined] combining steps before the [unspecified and undefined] comparing and storing steps are completed [for unspecified light sources], and thus the steps are not performed in the order required by the Court's claim construction." *Id*.

None of the vague "evidence" mentioned by Activision or relied upon by Judge Lynn, however, showed that, as a matter of law, Activision's accused games began the claimed combining step for any plurality of light sources before completing the comparing and storing steps for that plurality of light sources.

Indeed, Judge Lynn's statement of the question presented underscores the court's erroneous analysis – "do the '822 and '488 patents require that comparing and storing be completed for each light source before **any** combining begins? Or, put differently, can the accused games perform **other** 'compare,' 'store,' and **'combine' steps**—not relied on to show infringement—in any order, without impacting whether the accused games infringe the asserted claims?" Appx0019 (Summary Judgment Order at 18) (emphasis added). These "questions presented" wrongly assumes that the beginning of any combine step occurring before the completion of any comparing and storing for "each light source" precludes any

infringement as a matter of law. The correct answer to these questions is **no** – the asserted claims only require that, **for a plurality of light sources** (not each light source), the comparing and storing of specified data for that plurality of light sources be completed **before beginning of the claimed combining of "observer data," defined as including at least color data**, with light accumulation buffer data (not any undefined "combining"). Activision did not present evidence showing that, as a matter of law, Plaintiffs could not prove this, and Plaintiffs submitted evidence that Activision's accused games did perform these required steps in the specified order. Appx0467-Appx0477 (Infernal Resp. Mot. Exclude, Aliaga Report Black Ops 3 ¶¶ 277-305); Appx0484-Appx0493 (Aliaga Report Black Ops 4 ¶¶ 320-347); Appx0501-Appx0511 (Aliaga Report CoD IW ¶¶ 366-395); Appx0517-Appx0523 (Aliaga Report CoD WW2 ¶¶ 410-431); Appx0527-Appx0539 (Aliaga Report Skylanders/Alchemy ¶¶ 439-468); Appx0548-Appx0562 (Aliaga Report Crash ¶¶ 492-534); Appx0571-Appx0586 (Aliaga Report Destiny 1 ¶¶ 555-582); Appx0596-Appx0611 (Aliaga Report Destiny 2 ¶¶ 610-635); Appx0619-Appx0624 (Aliaga Report WoW WoD ¶¶ 663-683); Appx0625-Appx0634 (Aliaga Report Spyro ¶¶ 688-711).

Judge Lynn did not point to any evidence submitted by Activision showing that its accused games performed the claimed combining step before completing the comparing and storing steps. Instead, Judge Lynn incorrectly assumed away this

issue, asserting that "Plaintiffs do not dispute the factual basis of Activision's argument." Appx0018 (Summary Judgment Order at 17). This statement by the District Court, however, is incorrect. In particular, Plaintiffs stated in their opposition to Activision's motion that "Plaintiffs disagree with Activision's statement that '[f]or every accused game, after the completion of a "combining" step (defined in paragraph 22, above) for a first light source, the Accused Games perform additional "comparing" and "storing" steps for subsequent light sources.'" Appx2993 (Infernal's Resp. to Mot. For Summ. J. at 9). *See also Id*. at 9-10.

Judge Lynn incorrectly asserted that "Plaintiffs argue that there is at least one final combining step that begins after each light source has been compared and stored, and thus the fact that there may be intermediate combining steps before the comparing and storing steps are completed is irrelevant." Appx0019 (Summary Judgment Order at 18). Plaintiffs did not make such an argument. This actually was an argument made by Activision incorrectly describing Plaintiffs' argument. *See* Appx1796 (Activision's Brief ISO Mot. Summ. J. at 22). As explained above, Activision did not present any evidence showing that its accused games performed combining "observer data" with light accumulation buffer data before completing

the comparing and storing steps for the "plurality of light sources" – intermediate, final or otherwise.[9]

Moreover, Activision, as the movant, had the initial burden to demonstrate the absence of a genuine issue of material fact regarding the sequence of steps limitation. *See* discussion, *supra*, at Argument B.5. Activision did not satisfy this initial burden, and the District Court did not point to evidence in the record that it did.

The evidence cited by Activision did not show that Activision began the claimed combining step involving "observer data," (as that term was defined to include color data), before the completion of the comparing and storing steps for a plurality of light sources. Indeed, Activision describes the "attenLightColor" variable it relies upon to show "combining" out of order as "light image data" and not observer data including at least color data that must be combined to perform the step. APPX1798 (Activision's Brief ISO Mot. Summ. J. at 24). The "addition operation" Activision points to is actually a storing step involving adding the "attenLightColor" light image data to the light accumulation buffer. *See Id*. Activision then employs a series of convoluted arguments to attempt to show that the "attenLightColor" light image data "includes 'observer data.'" *Id*. The data

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[9] Neither the District Court nor Activision explained what constitutes an "intermediate" combining step compared to a "final" one.

Activision points to, however, is not "observer data" because it does not include observer color data. In sum, Activision made no showing that its accused games began the claimed combining step (involving "at least data representing the color of objects") with light accumulation buffer data before completing the comparing and storing steps. At a minimum, there is a genuine issue of material fact in dispute about this.

Moreover, Activision did not show that its accused games began the combining step before the completion of the comparing and storing steps for **any and every potential plurality of light sources** – a showing that was essential to entitle Activision to be entitled to summary judgment of noninfringement. Judge Lynn's Summary Judgment Order does not address this issue because, as discussed above, she wrongly assumed that **any** combining of **any data** before the completion of **any** comparing and storing steps was sufficient to make the sequence of steps "out of order," and wrongly assumed that it was undisputed that all of Activision's accused games began some form of "combining" before completing any comparing or storing steps. As shown above, neither of these assumptions was correct.

As Judge Lynn observed, Plaintiffs contended that Activision's additional so-called "combining" steps performed by the accused games "out of order" were "irrelevant" for purposes of determining infringement because they were "other," unrecited combining steps. Appx0018 (Summary Judgment Order at 17). Judge

Lynn noted that Plaintiffs argued that "'Activision's Accused Games can perform other 'compare,' 'store,' or 'combine' steps not required by the claims in any order without altering the fact that those games infringe.'" *Id*. Appx0018-0019 (Summary Judgment Order at 17-18). The District Court, however, wrongly rejected these arguments and Plaintiffs' evidence that Activision's accused games performed the recited steps in the proper order. In doing so, and in granting Activision's motion for summary judgment of noninfringement, the District Court committed reversible error.

Judge Lynn was wrong when she asserted that "it is undisputed that the accused games perform combining steps prior to the completion of the comparing and storing steps." Appx0022 (Summary Judgment Order at 21). Plaintiffs dispute that Activision has shown that its accused games began **the** combining step involving "observer data" that includes at least data representing the color of objects. If the District Court meant **any** combining steps, regardless of whether the step involved the claimed combining of "observer data," as defined by the District Court, then such additional, unrecited combining is, as Plaintiffs argued, irrelevant to the infringement analysis.

D. The District Court Committed Error by Excluding Plaintiff's Damages Expert Report Even Though It Employed a Proper and Accepted Methodology and the Estimated Reasonable Royalty Damages Were Tied to Activision's Extensive Use of the Infringed Method Claims

Judge Lynn, in rendering her Summary Judgment Order, ruled that the expert report of Plaintiffs' damages expert Gunderson should be excluded in its entirety on the stated ground that "the sole damages theory put forth by Gunderson is insufficiently tied to the facts of the case." Appx0022 (Summary Judgment Order at 21). Because this ruling is based on an erroneous view of the law and a clearly erroneous assessment of the evidence, this Court should reverse the ruling.[10]

1. The *Daubert* Standard

"When reviewing damages in patent cases, this Court applies regional circuit law to procedural issues and Federal Circuit law to substantive and procedural issues pertaining to patent law." *Whitserve, LLC v. Comput. Packages, Inc.*, 694 F.3d 10, 26 (Fed. Cir. 2012) (quoting *Wordtech Sys., Inc. v. Integrated Networks Sols., Inc.*, 609 F.3d 1308, 1318 (Fed. Cir. 2010)).

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[10] Although the Court's decision with regard to infringement will obviate the need to reach the damages issue at this time, it is possible that the identical damages issues will arise if infringement is found on remand. Thus, for purposes of judicial economy, the Court can and should review the damages issues briefed by the parties in this appeal. *Harris Corp. v. Ericsson Inc.,* 417 F.3d 1241, 1257 (Fed. Cir. 2005); *Rhodia Chimie v. PPG Indus.,* 402 F.3d 1371, 1375 n.2 (Fed. Cir. 2005).

This Court is well-versed with the requirements of Rule 702 of the Federal Rules of Evidence and the *Daubert* test for the admissibility of expert testimony. *See, e.g.*, *i4i Ltd. P'ship v. Microsoft Corp.*, 598 F.3d 831, 852 (Fed. Cir. 2010), *aff'd*, 564 U.S. 91 (2011). "The proponent need not prove to the judge that the expert's testimony is correct, but she must prove by a preponderance of the evidence that the testimony is reliable. *Moore v. Ashland Chem. Inc.*, 151 F.3d 269, 276 (5th Cir. 1998). It is imperative for district courts to bear in mind that the *Daubert* regime does not enlist judges "as a replacement for the adversary system." *United States v. 14.38 Acres of Land*, 80 F.3d 1074, 1078 (5th Cir. 1996); *see Dearmond v. Wal–Mart La. LLC*, 335 F. App'x 442, 444 (5th Cir. 2009) (stating cross examination is the way to discredit testimony and credibility is within a jury's province).

2. Patent Infringement Damages

Patent damages are governed by 35 U.S.C. § 284, whereby the court is required "upon finding for claimant" to "award the claimant damages adequate to compensate for the infringement but in no event less than a reasonable royalty for the use made of the invention by the infringer."

In this case, Plaintiffs sought reasonable royalty damages. In determining a reasonable royalty, the finder of fact may consider the factors set out in *Georgia–Pacific Corp. v. U.S. Plywood Corp.*, 318 F. Supp. 1116 (S.D.N.Y. 1970) ("the *Georgia–Pacific* factors"). *See Lucent*, 580 F.3d at 1325. "A key inquiry in the

analysis is what it would have been worth to the defendant, as it saw things at the time, to obtain the authority to use the patented technology, considering the benefits it would expect to receive from using the technology and the alternatives it might have pursued." *Carnegie Mellon*, 807 F.3d at 1304 (citing *AstraZeneca AB v. Apotex Corp.,* 782 F.3d 1324, 1334–35 (Fed. Cir. 2015)).

Critical to the resolution of this appeal is the principle of patent infringement damages that a plaintiff is entitled to seek damages measured by "the value of the benefit conferred to the infringer by ***use*** of the patented technology," *Powell v. Home Depot, Inc.*, 663 F.3d 1221, 1240 (Fed. Cir. 2011), and that the value of that benefit can include revenues derived from the sale of products which, by themselves, do not infringe an asserted method patent. *Carnegie Mellon Univ. v. Marvell Tech. Grp., Ltd.*, 807 F.3d 1283, 1306 (Fed. Cir. 2015).

In *Carnegie Mellon,* this Court upheld the district court's ruling that it was proper to measure the patentee's reasonable royalty for the defendant's infringing use of the method claims during the sales cycle by the value of the sales of products that resulted from that infringing use, even if sales of those products were not asserted to be acts of infringement. 807 F.3d at 1306. As the trial court in that case pointed out, Federal Circuit precedent "does not require a reasonable royalty to be tied only to use of the patented method (*i.e.*, infringement)." *Id*. at 610 (citing *Lucent Techs., Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1334 (Fed. Cir. 2009)). "Further," the

trial court emphasized, "one of the simplest ways to determine the value of an infringing use of a patented method during research is to ascertain how many sales were made based on that infringing use." *Id*.

On appeal, the Federal Circuit upheld the trial court's rulings on this issue and declared that "it makes no sense to insist that the action respecting the product being used for measurement itself be an *infringing* action. Thus, here the claim is a method claim, but the damages-measuring product practices the method in its normal intended use." *Id*. at 1306.

The Federal Circuit also upheld the trial court's jury instruction, which stated: "To the extent, however, that Marvell achieved sales resulting from Marvell's alleged infringing use during the sales cycle, you may consider them in determining the value of the infringing use." The Federal Circuit held that "[t]he jury properly was told that it 'may consider' any sales that resulted from the infringing use in order to value that use: for the reasons stated above, consideration of such sales was a sound part of determining the reasonable royalty for the infringing use." *Id*. at 1310. As the Federal Circuit held, "Marvell's sales are strongly enough tied to its domestic infringement as a causation matter to have been part of the hypothetical-negotiation agreement." *Id*. at 1307.[11]

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[11] Even Activision's own damages expert witness – who served as the damages expert witness for the plaintiff in the *Carnegie Mellon* case – confirms that using

3. The Gunderson Damages Opinion Was Based Upon Well-Established Damages Principles and Methods and Tied to the Facts of the Case

Gunderson's expert report on damages followed well-established principles and methodologies for analyzing damages in patent infringement cases. Gunderson applied the well-accepted *Georgia-Pacific* factors to the facts of this case for each type of asserted infringement to estimate the reasonable royalty that Activision would have paid for the right to use the inventions of the asserted claims. Among those *Georgia-Pacific* factors is Factor 11, which provides for the jury's consideration of "[t]he extent to which the infringer has made use of the invention, and any evidence probative of the value of that use." *Id.* at 1333. Plaintiffs have submitted substantial evidence showing that Activision's sale of its accused video games results from its testing and demonstration of those games. The strength of this evidence is a fact issue for a jury to decide.

In excluding the Gunderson damages opinion, Judge Lynn made several errors. First, she asserted that "Gunderson does not analyze the economic harm of the alleged use of the claimed methods during game testing and development or during game demonstrations," Appx0025 (Summary Judgment Order at 24), borrowing an argument from Activision's motion. Appx4088 (Activision's Brief

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sales of a product to measure the value to an infringer from testing the product can be proper. Appx4331 (Infernal Resp. Mot. Exclude, Lawton Dep. at 28:11-21).

ISO Mot. to Exclude at 4). This assertion is wrong. The economic harm to Plaintiffs from Activision's infringement of the asserted method claims is Activision's failure to compensate Plaintiffs through a reasonable royalty for its unauthorized use of the asserted method claims during testing and demonstration of the accused games. Section 284 provides for, at a minimum, a damages award of a reasonable royalty to compensate Plaintiffs for that infringement. 35 U.S.C. § 284. Gunderson's damages expert report thoroughly analyzed the relevant data to determine, under the *Georgia-Pacific* factors and the precedent of this Court, the amount of the reasonable royalty damages adequate to compensate Plaintiffs.

Even Activision's own damages expert refutes this conclusion when she confirmed that Carnegie Mellon was harmed by Marvell's infringement of the asserted method claims through testing because the infringement impaired the "ability to license" the claims "when people who were using the invention were not willing to take a license." Appx4332-Appx4333 (Infernal Resp. Mot. Exclude, Lawton Dep. at 37-38) ("[T]o the extent that the infringement affected Carnegie Mellon's ability to license the technology, they were certainly adversely affected.") Similarly, Plaintiffs have been harmed by Activision's infringing use of the asserted method claims through testing of the accused games by negatively impacting their ability to license the claims to Activision or others.

Judge Lynn acknowledged this Court's decision in *Carnegie Mellon*, and that, "in some instances, it may be appropriate to base damages for internal use of a claimed method on product sales." Appx0025 (Summary Judgment Order at 24). "But," Judge Lynn stated, "to do so there must be some connection between the accused infringer's use of the method and subsequent sales." *Id*. The District Court's assertion, however, that Gunderson "makes no effort to tie the claimed damages base to Activision's internal use of the patented method" is also completely wrong.

Gunderson's expert report on damages contains numerous and detailed references to the deposition testimony of Activision witnesses, Activision documents and testimony from Plaintiffs' technical expert regarding the exhaustive testing and demonstration throughout the development and marketing cycles of each of the accused games and how important such testing and demonstration was to Activision's sales of those games.

For example, Gunderson's report discusses the evidence that "[v]ideo game testing is an important step in video game development." Appx4512 (Infernal Resp. Mot. Exclude, Gunderson Report at ¶ 14). Gunderson's report cites evidence showing that video game testing "'is the factor that decides whether the game succeeds or not'" and that "'[v]ideo game testing is crucial to the gaming industry.'" Gunderson points to the evidence that video game testing "'is an

integral part of the game development process as it allows developers to analyze the game and identify, document and fix any software defects that may hamper the overall gaming experience [that] ensures that the end product performs at optimum levels and maintains quality throughout the game.'" *Id*. Gunderson's expert report also points to Activision documents explaining an "'additional purpose of the QA testing process is to identify issues that if addressed, will improve the quality of the title and generate better reviews, improving the overall quality of the title, and ensuring protection of the [] intellectual property, as well as the Activision reputation of producing quality game titles.'" Appx4522 (Infernal Resp. Mot. Exclude, Gunderson Report at ¶ 31).

Gunderson also points to substantial evidence regarding how Activision thoroughly tests the accused games throughout their development and production. Appx4521-4524 (Infernal Resp. Mot. Exclude, Gunderson Report at ¶¶ 30-34). This evidence included deposition testimony of several Activision executives regarding Activision's extensive testing of accused games before public release "to ensure compatibility with appropriate hardware systems and configurations and to minimize the number of bugs and other defects." Appx4522 (Infernal Resp. Mot. Exclude, Gunderson Report at ¶ 31) (quoting Christian Arends, Activision's Senior Director and Head of Worldwide Quality Assurance.) These Activision executives also confirmed that "all of the Accused Games were tested by Activision's QA

department prior to being released for publication and sale." Appx4522 (Infernal Resp. Mot. Exclude, Gunderson Report at ¶ 31).

In addition, Plaintiffs' technical expert, Dr. Daniel Aliaga, submitted an expert report that explains in detail the importance of Activision's testing of the accused games to Activision's sales of those games. In that report, Dr. Aliaga states:

> I have been asked to provide my opinion on the effect of testing and demonstration for the sales of games. It is my experience that **testing during the development of software, such as video games, through various debugging procedures and QA testing, is vital to the successful release of software**. In addition to testing that is done during development with various debugging and QA testing measures, postproduction testing that is performed through various means such as reviewing crash reports and releasing patches, is vital to the success of each individually sold game. **Without such testing done during development to ensure the games going out the door are polished and playable and post-production testing of the game engine, the overall success of the game would be negatively impacted as the games would present various glitches and, in some circumstances, would not even be functional**.

Appx4427-4428 (Infernal Resp. Mot. Exclude, Aliaga Report at ¶ 714) (emphasis added).

Dr. Aliaga further states that:

> The importance of testing can be seen from the way Activision prepares the Accused Games for publishing. **Activision tests all of the games it develops**. Activision has stated that "[a]nother aspect handled during quality assurance testing is verifying compliance with the protocols of various game consoles." **It is clear that this testing is vital to the ability of the Accused Games to be played on gaming consoles and thus sold to consumers**. Furthermore, Activision seeks out "Playtesters" from the public in order to test its unreleased games. **These playtests are done for the purpose of**

> **making Activision's games better, thus reemphasizing the importance of testing for the success and increased sales of the Accused Games**.

Id. Appx4428-4429 ¶ 715 (emphasis added).

Judge Lynn acknowledged much of this evidence, but merely asserted that "the Court disagrees with this evidence." *See* Appx0026 (Summary Judgment Order at 25).[12] "At most," Judge Lynn asserted, "Plaintiffs' evidence establishes that testing games before release is generally important to game development. However, Plaintiffs' evidence does not establish that testing affects sales; Gunderson's report focuses on testing as a means to ensure the quality of the games being produced, but does not tie increasing game quality to an impact on sales." *Id*. These comments, however, reflect the District Court's improper weighing of the evidence and injecting itself as the final arbiter of the persuasiveness of Plaintiffs' evidence regarding damages. Highly illustrative of this improper weighing of the evidence is the District Court's acknowledgment that, "while Dr. Aliaga opines that failure to test would negatively impact a game's success, he does not state the inverse—*i.e.*, that testing positively impacts sales, and if so, how." *Id*. Appx0027 (Summary Judgment Order at 26). It would be reasonable, however, for a jury to reach the

[12] Regarding Plaintiffs' evidence, the District Court commented that "[t]here is no mention in these cited paragraphs of deferred rendering, image quality, light sources, or anything relating specifically to the claimed method." *Id*. Gunderson, however, was a damages expert, and not an expert on liability. He is allowed to assume infringement and causation of damages. *See* discussion, *infra*, at Argument D.4.

inverse conclusion. Judge Lynn, therefore, applied the wrong legal standard for deciding the admissibility of Gunderson's expert report under *Daubert* – whether she agreed with the correctness of the opinions in the report.

In view of the evidence in the record, Judge Lynn's decision to exclude the Gunderson expert report on the ground that "Gunderson does not identify a nexus between the alleged infringement of the method claims and sales [of the accused games]," Appx0024 (Summary Judgment Order at 23), that "Mr. Gunderson wholly fails to consider the economic harm to Plaintiffs *caused by Activision's testing and demonstrations* of the accused games during game development," that "Gunderson's opinion regarding damages relies entirely on sales of the accused Games,"[13] *id*., and that a "nexus between internal use of the patented method and sales [] is wholly absent here" reflects a "clearly erroneous assessment of the evidence." *Id.*

The District Court's clearly erroneous assessment of the evidence of a nexus between Activision's infringement of the method claims through Activision's extensive testing and demonstration of the accused games and its sales of those

[13] This statement is clearly erroneous factually, given that Gunderson's estimate of reasonable royalty damages for infringement of the asserted method claims is based upon Activision's extensive testing and demonstration of the accused games, and sales of those games are the **metric for** measuring the value to Activision of that infringement. *See* discussion, *supra*, at Argument D.2.

games is even more difficult to understand in view of the District Court's acknowledgment that, especially in the *Daubert* motion context, Plaintiffs need only show "some connection between the accused infringer's use of the method and subsequent sales." Appx0025 (Summary Judgment Order at 24. Indeed, this Court in *Genband US LLC v. Metaswitch Networks Corp.*, 861 F.3d 1378 (Fed. Cir. 2017), rejected the contention that, in the context of showing a causal nexus between alleged infringement and the entitlement to injunctive relief regarding a product, the patentee must prove that the infringing feature was "the driver" of demand for the purchase of a product. *Id*. at 1381-82. Instead, this Court found that "a standard of the less demanding variety" was appropriate – "a driver" instead of "the driver" of demand for the product in question. *Id*. at 1382. This Court found that "a driver" standard "is the governing one for what suffices to meet the causation component of the requirement of irreparable injury, *i.e.*, that the injury asserted to be irreparable be injury *from the defendant's use of infringing features*." *Id*. (emphasis in the original) Under this or any reasonable standard for showing a nexus between infringement of a method claim through the testing of a product and sales of the product, the District Court's conclusion that Plaintiffs did not make a showing of a nexus between the two was clearly erroneous.

4. Gunderson, as Plaintiffs' Damages Expert, Did Not Have to Offer an Opinion on the Issue of Casual Nexus, Which Could be Shown Through Other Sources of Proof

Judge Lynn also wrongly criticized Gunderson for "seemingly assum[ing] . . . that all sales of the accused games are attributable to Activision allegedly performing the claimed method internally during testing and demonstrations." Appx0025 (Summary Judgment Order at 24). The District Court's error in this criticism is that a damages expert is allowed to assume as true the allegations of liability, including any allegation of causation relating to the connection between an act of infringement and its impact on a hypothetical negotiation of a reasonable royalty.

This principle was articulated clearly in the decision in *Robroy Indus.-Texas, LLC v. Thomas & Betts Corp.*, No. 2:15-CV-512, 2017 WL 1319553 (E.D. Tex. Apr. 10, 2017). This decision, by Judge Bryson sitting by designation, discussed at length this well-established principle when rejecting a defendant's motion to exclude the plaintiff's damages witness on the ground that the damages expert's report did not contain opinions by the expert regarding the issue of whether the damages calculated by the expert were caused by the alleged wrongdoing by the defendant. *Id*. (citing and discussing

U.S. Gypsum Co. v. Lafarge N. Am. Inc., 670 F. Supp. 2d 737 (N.D. Ill. 2009), "noting that the witness 'does not seek to opine that the assumptions

underlying her analysis are true in fact. [The witness] is an expert on damages, not liability, and she seeks to opine only on what the damages should be *if* the jury separately finds the facts she assumes to be true.'"

The *Robroy* court found that the damages expert witness in that case "is allowed to assume liability and address only the issue of damages. To prove causation, Robroy will be required—and will be permitted—to look to evidence other than the testimony of [the damages expert witness]." 2017 WL 1319553, at *4. Thus, the *Robroy* court rejected the defendant's argument that, in that case, a damages expert must also testify regarding causation. *Id*.

The *Robroy* court cited and discussed a plethora of cases that stand for the principle that a damages expert is entitled to assume causation in rendering his or her opinion on the issue of damages. The court stated that this principle "is beyond serious challenge." *Id*. at *5.[14] Activision did not dispute this legal principle, and

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[14] The *Robroy* court cited *Luitpold Pharms., Inc. v. Ed. Geistlich Sohne A.G. für Chemische Industrie*, No. 11-cv-681, 2015 WL 5459662, at *10 (S.D.N.Y. Sept. 16, 2015) ("[A] damages expert does not need to perform her own causation analysis to offer useful expert testimony."); *Gaedeke Holdings VII, Ltd. v. Baker, Case No*. CIV-11-649, 2015 WL 11570978, at *3 (W.D. Okla. Nov. 30, 2015) ("Proof of causation often comes from fact witnesses, and it is appropriate for expert witnesses to assume causation will be established and then proceed to calculate the damages.")

Judge Lynn did not discuss it in her Summary Judgment Order. Courts have continued to follow this principle articulated in *Robroy*.[15]

Thus, to be admissible, Gunderson's expert report did not need to contain an opinion on the issue of whether or not Activision's infringement of the asserted method claims through testing and demonstration caused Activision's sales of the tested and demonstrated accused games. Gunderson's expert report cited to evidence in the record from which a jury could infer this fact. *See Finjan, Inc. v. Sophos, Inc.*, 244 F. Supp. 3d 1016, 1045–46 (N.D. Cal. 2017). It was up to the jury, and not Judge Lynn, to determine if Plaintiffs' evidence of a nexus was sufficient to prove the alleged causation.

5. There is Nothing Improper about Gunderson Using a "Unitary Damages Model" Estimating the Reasonable Royalty Damages for Infringement of the Method and Apparatus Claims

The District Court also concluded that, "because Gunderson presents a unitary damages theory and does not indicate which portion of his proposed royalty is based on alleged infringement of the method claims versus the asserted apparatus claim (claim 27 of the '488 patent), his entire testimony must be excluded." Appx0026

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[15] *See, e.g., Indect USA Corp. v. Park Assist, LLC*, 2021 WL 4311002, at *1 (S.D. Cal. Sept. 22, 2021) ("[I]t is well established that experts on damages can assume causation. . . . Nor must a damages expert establish causation before his or her opinion becomes admissible"); *BladeRoom Grp. Ltd. v. Facebook, Inc.*, 2018 WL 1611835, at *3 (N.D. Cal. Apr. 3, 2018) (same) (citation omitted).

(Summary Judgment Order at 25). The problem here is that Judge Lynn did not provide any explanation or authority regarding why this fact justifies exclusion of the Gunderson expert report, and there is none.[16]

In a case where the estimated damages for infringement of an apparatus claim differ from the estimated damages for infringement of a method claim, the difference should be discernable, as it is in this case. For example, Judge Lynn observed that Gunderson's report identifies damages measured by domestic sales of the accused games, which applies to infringement of the asserted method claims and the asserted apparatus claim, and identifies additional damages measured by foreign sales of such games. Appx0023 (Summary Judgment Order at 22). The damages measured by foreign sales are attributable only to infringement of the method claims, because the alleged infringement of those method claims through testing and demonstration occurred in the United States, but the resulting sales occurred outside the United States (not infringing activity regarding the apparatus claims). Appx4306-4308 (Infernal's Resp. to Mot. to Exclude at 13-15); s*ee also id.* Appx4525-4527 ¶¶ 37-38**)** (calculating damages based on Activision's sales to customers worldwide

[16] Gunderson **does** provide an apportionment analysis regarding the value to Activision of its use of the patented features versus unpatented features of its accused games, as required by precedent. *See VirnetX, Inc. v. Cisco Sys., Inc.* , 767 F.3d 1308, 1327 (Fed. Cir. 2014). Appx4588-4593 (Infernal Resp. Mot. Exclude, Gunderson Report at ¶¶ 153-164.

which were the result of Activision's infringement of the Asserted Patents in the United States.)

Thus, the jury, with the appropriate instructions and verdict form, can award non-duplicative reasonable royalty damages for infringement of the asserted apparatus claim (measured by domestic sales of the accused games) separate and apart from reasonable royalty damages for infringement of the asserted method claims (also measured by the same domestic sales of the accused games and, additionally, foreign sales of the accused games if the jury finds those sales resulted from Activision's domestic infringement of the method claims.)

There is no requirement to "apportion" between damages for domestic infringement of the asserted method claims and the asserted apparatus claim because the amount of damages for each is the same (measured by domestic sales of the accused games). Gunderson did not have to "apportion" damages between the patents-in-suit or the infringement of method versus apparatus claims in order to provide the jury with evidence supporting the claimed amount of damages sought. One must simply guard against potential duplicative damages, which, as explained above, can be done through the proper jury instructions and verdict form.

The concept of "unitary damages" does not even appear to exist in patent infringement jurisprudence. It does appear in misappropriation of trade secret jurisprudence involving claims based upon multiple, distinct alleged trade secrets,

each having its own value for damages purposes. *See, e.g., DSC Commc'ns Corp. v. Next Level Commc'ns*, 107 F.3d 322, 330 (5th Cir. 1997). In most jurisdictions, a party is not obligated to apportion damages for each instance of wrongful conduct alleged, as unitary damages models are permissible in those jurisdictions. *See, e.g., Bildon Farms, Inc. v. Ward County Water Improvement Dist. No. 2,* 415 S.W.2d 890, 896 (Tex. 1967) (unitary damages allowed under Texas law). As long as the jury is provided an evidentiary basis for awarding damages for the wrongful conduct found, a "unitary damages" model is legally proper. *See, e.g., Steves & Sons, Inc. v. JELD-WEN, Inc.*, No. 3:16-CV-545, 2018 WL 2172502, at *12 (E.D. Va. May 10, 2018). The court in *Steves & Sons* upheld the "unitary" damages model in that case because it " has not 'left [the jury] without sufficient evidence, or a reasonable basis, to determine [JELD–WEN's] unjust enrichment damages.'" *Id*. at *12 (quoting *02 Micro Int'l Ltd. v. Monolithic Power Sys., Inc.*, 399 F. Supp. 2d 1064, 1077 (N.D. Cal. 2005).

In this case, Gunderson's expert report provides an evidentiary basis for a jury to award Plaintiffs the damages for the asserted infringement of the method and apparatus claims. Appx4519, Appx4525-4527, Appx4596-4597 (Gunderson Report at ¶¶ 27, 37-38, 169-170); Appx4619-4620, Appx4627-4632, Appx4643 (Gunderson Report at Ex. 4-5, 12-17, 28).

Moreover, even if the jury decided that the reasonable royalty damages for Activision's infringement of the asserted method claims was not the same for Activision's infringement of the asserted apparatus claim, the Gunderson report provides the jury with the information that jury would need to adjust the amount of the reasonable royalty damages for each type or extent of infringement by the jury. *Id*.[17]

Thus, not only is Judge Lynn's decision to strike the Gunderson report improper because it is based upon a hypothetical and speculative scenario, it is also improper because the Gunderson report provides the jury with the facts necessary for it to base an alternative calculation of damages if the hypothetical scenario actually arose.

CONCLUSION

For all the foregoing reasons, this Court should reverse Judge Lynn's Order granting Activision's Motion for Summary Judgment of Noninfringement, and remand for further proceedings. In addition, this Court should vacate Judge Lynn's Order excluding the expert report of Plaintiffs' damages expert, and remand for further proceedings.

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[17] The court in *Steves & Sons* observed that a unitary damages model is less of a concern, "[w]hen damages are based upon a reasonable royalty," because "the calculation 'necessarily involves an element of approximation and uncertainty.'" *W.L. Gore & Assocs.*, 872 F. Supp. 2d at 893 (quoting *Unisplay, S.A. v. Am. Elec. Sign Co.*, 69 F.3d 512, 517 (Fed. Cir. 1995)).

Respectfully submitted,

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CERTIFICATE OF COMPLIANCE

Case Number 21-2349

Appellants' Opening Brief

The foregoing filing complies with the relevant type-volume limitation of Federal Rules of Appellate Procedure and Federal Circuit Rules because the filing has been prepared using a proportionally spaced typeface and includes 13,954 words.

Date: December 3, 2021

/s/ Eric W. Buether
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CERTIFICATE OF SERVICE

I certify that I served a copy on counsel of record on December 3, 2021, via electronic means using the CM/ECF System, which will serve via email notice of the Appellants' Non-Confidential Opening Brief, and I certify that I served a copy of the Appellants' Confidential Opening Brief via electronic mail to the following counsel registered as CM/ECF users:

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Upon acceptance by the Court of the e-filed document, six (6) paper copies of Appellants' Confidential Opening Brief will be filed with the Court, via Federal Express, within the time provided in the Court's rules.

Date: December 3, 2021

<u>/s/ Eric W. Buether</u>
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ADDENDUM

TABLE OF CONTENTS

APPELLANT'S OPENING BRIEF

JUDGMENT AND ORDERS APPEALED FROM

PATENTS-IN-SUIT

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF TEXAS
DALLAS DIVISION

INFERNAL TECHNOLOGY LLC et al.,	§	
	§	
Plaintiffs,	§	
	§	
v.	§	Civil Action No. 3:18-cv-01397-M
	§	
ACTIVISION BLIZZARD INC.,	§	
	§	
Defendant.	§	
	§	
	§	

JUDGMENT

The Court previously granted Defendant Activision Blizzard Inc.'s Motion for Summary Judgment of Noninfringement. In accordance with that Order, it is

ORDERED, ADJUDGED, AND DECREED that judgment is entered in favor of Defendant Activision Blizzard Inc. and against Plaintiffs Infernal Technology LLC and Terminal Reality, Inc. Defendant does not infringe claim 1 of U.S. Patent No. 6,362,822 or claims 1 and 27 of U.S. Patent No. 7,061,488. Plaintiffs shall take nothing on their claims of infringement against Defendant. All costs of court are taxed against Plaintiffs.

Signed this 16th day of September, 2021.

Barbara M G Lynn

BARBARA M. G. LYNN
CHIEF JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF TEXAS
DALLAS DIVISION

INFERNAL TECHNOLOGY LLC et al.,	§	
	§	
Plaintiffs,	§	
	§	
v.	§	Civil Action No. 3:18-cv-01397-M
	§	UNDER SEAL
ACTIVISION BLIZZARD INC.,	§	
	§	
Defendant.	§	
	§	
	§	

<u>MEMORANDUM OPINION AND ORDER</u>

Before the Court is Defendant Activision Blizzard Inc.'s Motion for Summary Judgment of Noninfringement and Invalidity (ECF No. 243), Plaintiffs' Motion for Partial Summary Judgment of No Invalidity (ECF No. 240), Activision's Motion for Leave to File a Sur-Reply (ECF No. 299), Activision's Motion to Exclude the Opinions of Plaintiffs' Damages Expert Lance Gunderson and Technical Expert Daniel Aliaga (ECF No. 270), Plaintiffs' Motion to Strike Portions of Dr. Scott Schaefer's Expert Report Regarding Invalidity (ECF No. 267), and Plaintiffs' Motion to Strike Portions of Anthony J. Pelham's Expert Report Regarding Invalidity (ECF No. 264).

Activision's Motion for Leave to File a Sur-Reply is **GRANTED.** For the reasons stated below, Activision's Motion for Summary Judgment of Noninfringement is **GRANTED**, and Activision's Motion to Exclude the Opinions of Plaintiffs' Damages Expert Lance Gunderson is **GRANTED**. The remainder of the Motions are **DENIED AS MOOT.**

I. Background

Plaintiffs Infernal Technology LLC and Terminal Reality, Inc. brought this action against Defendant Activision Blizzard Inc. ("Activision"), alleging infringement of United States Patent Nos. 6,362,822 (the "'822 patent") and 7,061,488 (the "'488 patent") (together, the "asserted patents"). The application that issued as the '488 Patent is a continuation of the application that issued as the '822 Patent, which was filed on March 12, 1999. Each of the asserted patents is entitled "Lighting and Shadowing Method and Arrangements for Use in Computer Graphic Simulations." The asserted patents are directed to technology for handling lighting and shadowing in computer graphics. Plaintiffs allege that certain Activision video games infringe claim 1 of the '822 patent, and claims 1 and 27 of the '488 patent (collectively, the "asserted claims").[1]

Activision moves for summary judgment of noninfringement and invalidity, arguing that there is no genuine dispute of material fact that the accused games do not infringe any of the asserted claims, and that all of the asserted claims are directed to patent ineligible abstract ideas under 35 U.S.C. § 101. Activision further moves to exclude the opinions of Plaintiffs' damages expert Lance Gunderson and technical expert Dr. Daniel Aliaga. Plaintiffs move for summary judgment of no invalidity, arguing that the asserted claims are not anticipated or rendered obvious by the "RenderMan" or "PixelFlow" prior art systems, and that the asserted patents are not invalid for lack of sufficient written description or enablement. Plaintiffs also move to exclude certain invalidity opinions of Activision's experts Dr. Scott Schaefer and Anthony J. Pelgram.

[1] Plaintiffs initially asserted claims 1, 2, 3, 4, and 7 of the '822 patent, and claims 1, 6, 27, 28, 29 of the '488 patent. Following the August 16, 2021, hearing on the parties' dispositive motions and motions to strike, Plaintiffs withdrew their claims of infringement for Claims 2-4 and 7 of the '822 Patent, and Claims 6, 28, and 29 of the '488 Patent. *See* Notice of Withdrawal of Certain Claims, ECF No. 340.

a. Asserted Claims

Claim 1 of the '822 patent claims the following:

> [1(pre)] 1. A shadow rendering method for use in a computer system, the method comprising the steps of:
>
> > [1(a)] providing observer data of a simulated multi-dimensional scene;
> >
> > [1(b)] providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;
> >
> > [1(c)] for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in a light accumulation buffer; and then
> >
> > [1(d)] combining at least a portion of said light accumulation buffer with said observer data; and
> >
> > [1(e)] displaying resulting image data to a computer screen.

'822 patent, at cl. 1.

Independent claim 1 of the '488 patent is nearly identical to claim 1 of the '822 patent, with two exceptions: it omits "for use in a computer system" in the preamble, and in the final step 1(e), it requires "outputting resulting image data" instead of "displaying resulting image data to a computer screen." Independent claim 27 of the '488 patent claims the following:

> [27(pre)] 27. A computer-readable medium carrying at least one set of computer instructions configured to cause at least one processor to operatively render simulated shadows in a multi-dimensional simulated scene by performing the steps of:
>
> > [27(a)] providing observer data of a simulated multi-dimensional scene;
> >
> > [27(b)] providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;
> >
> > [27(c)] for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing

> at least a portion of said light image data associated with said point and said light source in a light accumulation buffer; and then
>
> [27(d)] combining at least a portion of said light accumulation buffer with said observer data; and
>
> [27(e)] outputting resulting image data.

’488 patent, at cl. 27

Relevant to this Order, this Court previously construed “observer data of a simulated multidimensional scene” to mean “data representing at least the color of objects in a simulated multidimensional scene as viewed from an observer’s perspective.” ECF No. 105 (“*Markman* Order”), at 39. The Court also previously construed “combining at least a portion of said light accumulation buffer with said observer data” to mean “combining at least a portion of the data in the light accumulation buffer with said observer data,” and construed “at least a portion of” to have its plain and ordinary meaning. *Id.* at 39–40. Finally, this Court construed “the order of the comparing, storing, and combining steps,” to mean that “the comparing and storing steps are completed before beginning the combining step.” *Id.* at 40.

b. Accused Games

Plaintiffs accuse the following 19 video games of infringing one or more of the asserted claims: Call of Duty: Black Ops 3; Call of Duty: Black Ops 4; Call of Duty: Infinite Warfare; Call of Duty: World War 2; Crash Bandicoot: N. Sane Trilogy; Destiny 1; Destiny 1: Rise of Iron; Destiny 1: The Dark Below; Destiny 1: The Taken King; Destiny 2; Destiny 2: Curse of Osiris; Destiny 2:Forsaken; Destiny 2: Warmind; Skylanders: Imaginators; Skylanders: SuperChargers; Skylanders: Swap Force; Skylanders: Trap Team; Spyro’s Reignited Trilogy; and World of WarCraft: Warlords of Draenor (collectively, the “accused games”).

II. Legal Standard

Summary judgment is proper when there is no genuine issue as to any material fact and the movant is entitled to judgment as a matter of law. Fed. R. Civ. P. 56(a). Once the movant shows that there is no genuine issue as to any material fact, the burden shifts to the nonmoving party to produce competent evidence showing the existence of a genuine issue as to a material fact. *Celotex Corp. v. Catrett*, 477 U.S. 317, 330 (1986). The Court views all evidence in the light most favorable to the party opposing the motion. *Applied Med. Res. Corp. v. U.S. Surgical Corp.*, 448 F.3d 1324, 1331 (Fed. Cir. 2006).

III. Analysis

a. Activision's Motion for Summary Judgment of Noninfringement and Invalidity

Activision moves for summary judgment of noninfringement, arguing that there is no material dispute that the accused games do not infringe any of the asserted claims. Activision also seeks summary judgment of invalidity, arguing that the '822 and '488 patents are invalid and are directed to patent ineligible subject matter under 35 U.S.C. § 101.

Activision contends that summary judgment of noninfringement is appropriate because the accused games do not "combin[e] at least a portion of said light accumulation buffer with said observer data," which is a limitation in all asserted claims, and because the accused games do not perform the claimed steps in the order mandated by the claim language and the Court's claim construction. Activision alternatively argues for partial summary judgment of noninfringement because there is no evidence Activision performs the claimed method steps for the Destiny video games.

After considering the parties' briefing, arguments, the claim language, and the evidence presented, the Court concludes that summary judgment of noninfringement is warranted for all

asserted claims because the accused games do not satisfy the "combining" limitation, and because the accused games do not perform the claimed method in the sequence required by the Court's claim construction. Because these decisions are case dispositive, the Court does not reach the other grounds for summary judgment raised by Activision.

i. Legal Standard

In a patent case, an accused infringer moving for summary judgment of noninfringement must show that, when all reasonable factual inferences are drawn in favor of the patentee, no reasonable jury could find infringement. *Netword, LLC v. Centraal Corp.*, 242 F.3d 1347, 1353 (Fed. Cir. 2001). This determination requires a two-step analysis: (1) the claims must be properly construed by the Court to determine the scope and meaning of the claims; and (2) the allegedly infringing device or process must be compared to the construed claims. *C.R. Bard, Inc. v. U.S. Surgical Corp.*, 388 F.3d 858, 861 (Fed. Cir. 2004).

ii. The accused games do not "combin[e] at least a portion of said light accumulation buffer with said observer data."

Activision argues that the accused games do not practice "combining at least a portion of said light accumulation buffer with said observer data," which is a limitation present in all asserted claims. Activision's argument relies on the distinction between "observer data," "at least a portion of said observer data," and "said observer data," as shown in claim elements 1(a), 1(c), and 1(d) in representative Claim 1 of the '822 patent.[2]

[2] Because each asserted claim contains identical claim limitations requiring (a) "providing observer data . . .", (b) "for each of said plurality of light sources, comparing at least a portion of said observer data . . . ," and (d) "combining at least a portion of said light accumulation buffer with said observer data," the Court's analysis regarding elements 1(a), 1(c), and 1(d) in Claim 1 of the '822 patent applies equally to all asserted claims. The Court at times refers to these elements as the "providing," "comparing," and "combining," steps, respectively.

Activision's argument is two-fold. First, based on the plain and ordinary meaning of the claim language, Activision contends that "said observer data" used in the "combining" step (element 1(d)) refers to the same observer data from the "providing" step (element 1(a)). Put differently, Activision argues the observer data provided in 1(a) must be the same as what is combined in 1(d), and that the term "at least a portion of said observer data" in the "comparing" step (element 1(c)) refers to a subset of the observer data provided in 1(a).

Second, Activision argues, based on this interpretation, that Plaintiffs' evidence of infringement does not satisfy the combining step, because the observer data Plaintiffs' expert Dr. Aliaga identifies in the providing step consists of depth buffer and geometry buffer data, while the observer data Plaintiffs' expert identifies in the combining step consists of only a subset of geometry buffer data, namely albedo, diffuse, or other color data, depending on the accused game. In addition, Activision argues that Plaintiffs identify two different subsets of observer data for the comparing and combining steps, and thus cannot argue that the "said observer data" limitation in the combining step refers back to the "at least a portion of said observer data" limitation in the comparing step.

In their Response to Activision's Motion, Plaintiffs did not dispute the second, factual prong of Activision's argument—*i.e.*, that only a subset of the observer data from the providing step is subsequently combined. Instead, Plaintiffs argued that the asserted claims do not require that "all" the observer data from the providing step be used in the combining step. Resp. (ECF No. 258) at 24. At oral argument, Plaintiffs conceded that Dr. Aliaga describes "observer data" in the providing element 1(a) as consisting of other types of data in addition to the albedo or color data that is subsequently combined, and instead now assert a narrower infringement

position, relying solely on albedo data as the "observer data" for purposes of the providing, comparing, and combining steps in elements 1(a), 1(b), and 1(c), respectively.

1. The Meaning of "Said Observer Data."

As a preliminary matter, the Court will clarify the plain and ordinary meaning of "said observer data" in the comparing step (element 1(c)) and the combining step (element 1(d)).

Plaintiffs argue that Activision waived its argument by not raising the scope of "said observer data" at claim construction. During claim construction, the parties did not ask for a construction of "said observer data," because the proposed agreed construction for the combining limitation simply recites the same "said observer data" language at issue without any additional clarification. *See Markman* Order, at 12, 40. Activision responds that it is not proposing a new construction, but instead arguing that when "said observer data" is interpreted according to its plain and ordinary meaning, it does not infringe. The Court agrees with Activision; there is no waiver, as the Court is not construing the claim language, but rather applying the plain and ordinary meaning of the term in context with the other claim language. Moreover, even if a construction were necessary, "a district court may engage in claim construction during various phases of litigation, not just in a *Markman* order." *Conoco, Inc. v. Energy & Env't Int'l, L.C.*, 460 F.3d 1349, 1359 (Fed. Cir. 2006).

Here, numerous canons of claim construction and the claim language indicate that, under its plain and ordinary meaning, "said observer data" in 1(d) means the same observer data as the "observer data" in 1(a), and that "at least a portion of said observer data" in 1(c) means at least a portion of that same observer data provided in 1(a).

First, words in a claim should be interpreted consistently throughout the same claim. *See, e.g.*, *Digital Biometrics, Inc. v. Identix, Inc.*, 149 F.3d 1335, 1345 (Fed. Cir. 1998) ("[T]he same word appearing in the same claim should be interpreted consistently."); *Phonometrics, Inc. v.*

Northern Telecom Inc., 133 F.3d 1459, 1464 (Fed. Cir. 1998) ("A word or phrase used consistently throughout a claim should be interpreted consistently."). Thus, absent contrary direction from the specification or the claim language, "observer data" is presumed to have the same meaning throughout the claim.

Plaintiffs point to cases suggesting that identical claim terms need not have the same meaning in all instances. Resp. at 21–22 (citing *Microprocessor Enhancement Corp. v. Texas Instruments Inc.*, 520 F.3d 1367, 1375 (Fed. Cir. 2008), and *Epcon Gas Sys., Inc. v. Bauer Compressors, Inc.*, 279 F.3d 1022, 1031 (Fed. Cir. 2002)). However, both *Microprocessor Enhancement* and *Epcon Gas* upheld the general rule that a claim term should be construed consistently in the claim, but found that in those particular cases, the specific context of the term and the specification supported different interpretations of the same term. *See Microprocessor*, 520 F.3d at 1376 ("[T]he claims' apparent nonsensical reading under a uniform construction of [the term] is indicative of the ease of determining the appropriate meaning of each use of the term from its context."); *Epcon Gas*, 279 F.3d at 1031 ("The phrase "substantially constant" denotes language of approximation, while the phrase "substantially below" signifies language of magnitude, i.e., not insubstantial. Because the same term was used in a different manner in these two phrases, the word "substantially" should not necessarily be interpreted to have the same meaning in both phrases."). Here, the context of the claims—including the use of qualifying "at least a portion of" language in 1(c)—indicates that "observer data" should be interpreted consistently in 1(a) and 1(d), and Plaintiffs point to nothing warranting a contrary interpretation.

Second, the word "said" has been consistently interpreted by the Federal Circuit to reference a previous use of the same term. *E.g.*, *Summit 6, LLC v. Samsung Elecs. Co.*, 802 F.3d 1283, 1291 (Fed. Cir. 2015) ("The use of the term 'said' indicates that this portion of the claim

limitation is a reference back to the previously claimed 'pre-processing parameters.'"); *Raylon, LLC v. Complus Data Innovations, Inc.*, 700 F.3d 1361, 1376 (Fed. Cir. 2012) (Reyna, J., concurring) ("As our cases require, 'said' refers back to an earlier use of that term in the claim."); *Baldwin Graphic Sys., Inc. v. Siebert, Inc.*, 512 F.3d 1338, 1343 (Fed. Cir. 2008) (noting that the claim term "said" is an "anaphoric phrase[], referring to the initial antecedent phrase"). Thus, absent contrary direction from the specification, the phrase "said observer data" in claim 1 refers to the earlier appearance of "observer data."

Third, limitations must be construed in context and with the claim as a whole. *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312 (Fed. Cir. 2005) (en banc) ("[T]he person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification."); *ACTV, Inc. v. Walt Disney Co.*, 346 F.3d 1082, 1088 (Fed. Cir. 2003) ("While certain terms may be at the center of the claim construction debate, the context of the surrounding words of the claim also must be considered in determining the ordinary and customary meaning of those claims."). This includes giving weight to qualifying language present in one claim limitation and absent in another. *Helmsderfer v. Bobrick Washroom Equip., Inc.*, 527 F.3d 1379, 1382 (Fed. Cir. 2008) ("[D]ifferent claim terms are presumed to have different meanings."); *Allergan, Inc. v. Athena Cosmetics, Inc.*, 2009 WL 10700853, at *20 (C.D. Cal. Nov. 16, 2009) ("The expression of a limitation in one part of a claim implies its exclusion in another part where the limitation is not expressed.").

Thus, the qualifying language in 1(c)—that only "at least a portion of said observer data" is used in the comparing step—suggests that other instances of "said observer data" are not so qualified, otherwise the qualification in 1(c) would be superfluous. *See Bicon, Inc. v. Straumann*

Co., 441 F.3d 945, 950 (Fed. Cir. 2006) ("[C]laims are interpreted with an eye toward giving effect to all terms in the claim."). Put differently, the patentee would not need to specify that 1(c) requires that only a subset of the observer data be compared if "observer data" otherwise inherently provides that less than the observer data provided in 1(a) could satisfy the limitation.

Finally, the claims should be read in view of the specification. Here, the specification provides limited support either way, as it neither specifies that the combining step requires "all" observer data, or that the combining step can be performed with some subset of the data. Instead, the combining step is simply described as being performed with "the observer data." *E.g.*, '822 patent, at 3:32–35 ("Once this is completed, the method includes the steps of combining at least a portion of the light accumulation buffer with the observer data, and displaying the resulting image data to a computer screen."); *id.* at 5:10–12 (". . . combining at least a portion of the light accumulation buffer with the observer data . . . ."). Accordingly, the specification provides limited support for reading the claim language inconsistently with its plain and ordinary meaning described above.

Plaintiffs argue the specification "only disclose[s] combining *certain color values*, part of the 'observer data,' with a portion of the light accumulation buffer." Resp. at 25. Plaintiffs point to the Abstract and Figure 4 for support, neither of which warrant departing from the plain and ordinary meaning of the claim language discussed previously. *Id.* Plaintiffs rely on a single sentence in the Abstract describing how an accumulated light image is "combined with a *camera color image* to produce a lighted camera image" for display. '822 patent, Abstract (emphasis added). To the extent the italicized portion of the Abstract refers to the combining step in claim 1, it is weak evidence regarding the meaning of "said observer data" in that step, given that it describes combining a light image with "a camera color image"—a phrase never again

repeated in the patent—and there is no basis to limit "camera color image" to color data or data representing red-green-blue pixel ("RGB") values.[3] Plaintiffs' reliance on Figure 4 is similarly misplaced; Plaintiffs argue that based on Figure 4, "the Asserted Patents only contemplate combining the RGB color values in the camera view ('observer data') with the light accumulation buffer. . . . [A] POSITA would not understand that depth values would be combined with the light accumulation buffer to create an output image as required by the Asserted Claims." Resp. at 26. Figure 4 does indicate that camera view pixels are combined, but nowhere does it indicate the camera view pixels consist only of RGB color values. Moreover, Plaintiffs provide no citation or support for its assertion that a POSITA would understand that depth values would not be used to create an output image.

Plaintiffs' argument that "observer data" consists solely of color data is contradicted by other intrinsic evidence, including the plain language of the patents (discussed previously), limitations in dependent claims, and the parties' agreed construction. For example, claim 2 of the '822 patent—a previously asserted claim—specifies that "said observer" data includes color data *and* depth data:

> 2. The method as recited in claim 1, wherein <u>said observer data includes observed color data and observed depth data</u> associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

'822 patent, cl.2 (emphasis added).

[3] The specification refers to both "color data" and "red-green-blue (RGB) pixel data values"; RGB pixel data values are described as an example of "color data." *E.g.*, '822 patent, at 3:37–46 ("[T]he observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within the scene as rendered from an observer's perspective. Thus, for example, the modeled polygons can be associated with a single pixel on the computer screen or a group of pixels, wherein the observed color data includes an observed red-green-blue value for the pixel(s) and the observed depth data includes an observed z-buffer value for the pixel(s)."). The specification recognizes that those skilled in the art will recognizes that "other conventions and/or arrangements can also be used for storing and manipulating the data." *Id.* at 6:64–7:3.

In addition, during *Markman*, the parties agreed that "observer data of a simulated multidimensional scene" means "data representing *at least* the color of objects in a simulated multidimensional scene as viewed from an observer's perspective." *Markman* Order, at 39 (emphasis added). Thus, observer data includes, but is not limited to, color data, and may include additional data depending on Plaintiffs' infringement theory and contentions.

Plaintiffs point to Judge Wallach's dissent in *Harris Corp. v. Fed. Exp. Corp*., 502 F. App'x 957 (Fed. Cir. 2013), to argue that the reference to combining "said observer data" in 1(d) does not require combining all observer data. In that case, the majority construed a method claim referring to generating aircraft data, storing aircraft data, and transmitting the generated and stored aircraft data, as requiring that all the generated and stored aircraft data be transmitted. Judge Wallach dissented, arguing that because "the term 'all' is nowhere to be found in the claim language . . . defining [the limitation] to require transmitting 'all' of the . . . data accumulated is counterintuitive within the context of the claims." *Id.* at 971 (Wallach, J., dissenting).

However, the majority in *Harris* concluded that each reference in the claim to "aircraft data" referred to the same full set of data, as opposed to some subset. The majority reached that conclusion based on several of the same reasons analyzed here, including that claim language should be interpreted consistently within a claim, repeat use of a term refers to the earlier antecedent, and neither the claim language nor the specification suggested that any subset of the data should be used. *Harris*, 502 F. App'x at 963–64 (majority op.). If anything, this case presents a stronger case than *Harris*, given that here, the comparing step 1(c) includes qualifying language that specifies when less than the complete set of "observer data" may be used.

In sum, the qualifying claim language "at least a portion of said observer data" in the comparing step 1(c) shows that the patentee knew how to specify when a subset of the observer

data—as opposed to the whole—could be used. The patentee could have imported the same flexibility into the combining step 1(d), but chose not to. Accordingly, under its plain and ordinary meaning, "said observer data" in the combining step 1(d) refers to the same observer data as the "observer data" in the providing step 1(a), and "at least a portion of said observer data" in the comparing step 1(c) means at least a portion of that same observer data provided in step 1(a).

2. The accused games do not "combin[e] at least a portion of said light accumulation buffer with said observer data"

Activision argues that summary judgment of noninfringement is appropriate because, although the claim language requires the same observer data be used in steps 1(a) and 1(d), for each accused game, Plaintiffs' infringement expert Dr. Aliaga identifies only a subset of the observer data provided in 1(a) that is combined in step 1(d).[4] *See* ECF No. 46, ¶¶ 14–18. Specifically, for element 1(a), Activision cites paragraphs from Dr. Aliaga's report indicating that Plaintiffs identify as the "observer data" data that is derived from a "g-buffer, specifically 'world normal,' 'vertex normal,' 'albedo,' 'diffuse,' 'depth,' 'position,' or other 'normal vector' data." *Id.* ¶ 14. But for element 1(d), the combining step, Activision cites Dr. Aliaga's opinions that point to a subset of that observer data, namely "color data, such as 'albedo,' 'diffuse color,' 'specular color,' or other color data derived from a g-buffer for the 'said observer data' in this

[4] As an illustrative example, regarding the accused game *Call of Duty: Black Ops 3*, Dr. Aliaga describes the "Observer Data" as including depth buffers and geometry buffers: "[t]he depth buffer contains depth data values produced by rendering the scene from the camera's perspective, and the geometry buffers contain data such as, for example, diffuse albedo, surface normal, specular color, and glossiness values produced by rendering the scene from the camera's perspective." Aliaga Rep. ¶ 227, Def.'s App'x at Appx464 (ECF No. 247-1, at 11). For the 1(d) "combining" step, Dr. Aliaga identifies the function "ComputeFinalLighting" as satisfying the claim limitation, which relies on an "albedo" value. *Id.* ¶¶ 298–301 (ECF No. 247-1, at 20). Dr. Aliaga opines that the "'albedo' value . . . constitutes *observer data*" because it derives from a geometry buffer, "which contains diffuse color data values for objects in the scene." *Id.* Thus, for *Call of Duty: Black Ops 3*, Plaintiffs identify "observer data" provided in 1(a) as consisting of depth and geometry buffers, but only identifies a subset of that observer data—namely, albedo data derived from geometry buffers—as the "said observer data" for purposes of 1(d).

limitation." *Id.* ¶ 17. Activision further argues that for element 1(c), the comparing step, Dr. Aliaga identifies "'normal vector' and 'position' data as the 'observer data,'" which is different from the data Plaintiffs identify for element 1(d). *Id.* ¶ 16. Because the claim language requires that the "said observer data" in 1(d) be the same as that provided in 1(a), Activision contends that there is no factual dispute that Plaintiffs have not satisfied the claim element "combining at least a portion of said light accumulation buffer with said observer data" for any of the asserted games.

In their written response, Plaintiffs did not dispute the factual record put forth by Activision or point to any contrary evidence indicating that the observer data combined in element 1(d) is the same as initially provided in 1(a); instead, Plaintiffs argued that "said observer data" in 1(d) did not necessarily include "all" observer data provided in 1(a). Indeed, at oral argument, Plaintiffs conceded that Dr. Aliaga identifies more "observer data" in the providing step than the data which is subsequently combined. *E.g.*, Aug. 16, 2021, Hearing Tr. at 23:18–20 (Plaintiffs' counsel) ("We understand Dr. Aliaga has identified more than albedo as what can be included within the wide range of observer data . . . .").

During oral argument, Plaintiffs represented to the Court that they are no longer relying on the observer data identified by Dr. Aliaga for their infringement theory. Instead, Plaintiffs now posit that the same set of "albedo" data constitutes "observer data" for purposes of the providing step 1(a), the comparing step 1(c), and the combining step 1(d). *See id.* at 27:4–9 ("So if Plaintiffs narrow their case, as we are doing, to say that observer data in Step (a) is only albedo and, therefore, albedo is also in the comparing step and, finally, albedo is in the combining step, then we absolutely meet the Court's claim construction even in the manner in which Activision

is interpreting it."); *see also id.* at 26:5–6 ("[T]he infringement read that Plaintiffs are asserting is based on albedo, period.").

The Court notes that Plaintiffs did not make this argument in their written response; indeed, the word "albedo" does not appear once in Plaintiffs' brief in opposition to Activision's Motion for Summary Judgment. Moreover, Plaintiffs did not respond to or rebut Activision's recitation of facts that different subsets of observer data are compared in 1(c) than combined in 1(d). *See* ECF No. 46, ¶¶ 16–17 (noting that for 1(c), Plaintiffs rely on "normal vector" and "position" data as "at least a portion of said observer data," but cite color data, such as "albedo," as the observer data in 1(d)).[5] Put differently, the only evidence properly before the Court indicates that different sets of data are used in the comparing step and the combining step, and thus the Court is aware of no evidence that the same albedo data is used in the accused games in each of the 1(a), 1(c), and 1(d) steps.

Thus, even assuming Plaintiffs are permitted to raise this new theory of infringement at oral argument, Plaintiffs have failed to show a genuine issue of material fact that all elements of the asserted claims are met. Plaintiffs do not dispute that Dr. Aliaga identifies "said observer data" in element 1(d) as constituting only a subset of the observer data provided in 1(a), contrary to the plain and ordinary meaning of "said observer data," and to the extent there exists evidence in the record in support of Plaintiffs' new albedo-based infringement theory, it is not properly before the Court. *Malacara v. Garber*, 353 F.3d 393, 405 (5th Cir. 2003) ("When evidence exists in the summary judgment record but the nonmovant fails even to refer to it in the response

[5] Indeed, Plaintiffs' own summary judgment brief cites paragraphs of Dr. Aliaga's report identifying the "at least a portion of said observer data" used in the 1(c) comparing step as constituting something *other* than albedo data, namely position and depth data. *E.g.*, Resp. (ECF No. 258) at 13 (citing Aliaga Rep. ¶ 419, Def.'s App'x at Appx464 (ECF No. 247-1, at 54) ("[T]he 'offPosition' variable comprises *at least a portion of said observer data* because, for example, it derives from the 'depthTexture' buffer.")).

to the motion for summary judgment, that evidence is not properly before the district court."); *Ragas v. Tennessee Gas Pipeline Co.*, 136 F.3d 455, 458 (5th Cir. 1998) ("The party opposing summary judgment is required to identify specific evidence in the record and to articulate the precise manner in which that evidence supports his or her claim."); *cf. United States v. Dunkel*, 927 F.2d 955, 956 (7th Cir. 1991) ("Judges are not like pigs, hunting for truffles buried in briefs."). Accordingly, because the accused games do not "combin[e] at least a portion of said light accumulation buffer with said observer data," a limitation in all asserted claims, Plaintiffs have failed to raise a genuine issue of material fact that all claim elements are met, and the Court grants summary judgment of noninfringement on this basis.

iii. The accused games do not perform the claimed steps in order.

Summary judgment of noninfringement is appropriate for an additional reason. As discussed, the asserted claims each recite steps requiring, for each of a plurality of light sources, comparing light image data and storing it in a light accumulation buffer (*e.g.*, element 1(c)), and combining at least a portion of the light accumulation buffer with observer data (*e.g.*, element 1(d)). Under the Court's agreed construction, "the comparing and storing steps are completed before beginning the combining step." *Markman*, at 40.

Activision argues that summary judgment of noninfringement is appropriate because the accused games perform combining steps before the comparing and storing steps are completed, and thus the steps are not performed in the order required by the Court's claim construction. Plaintiffs do not dispute the factual basis of Activision's argument; instead, Plaintiffs contend that additional combining steps performed by the accused games out of order are irrelevant for purposes of determining infringement, "so long as there is a combination of a light accumulation buffer with the observer data occurring after the identified 'comparing' and 'storing' steps are completed for a plurality of light sources." Resp. (ECF No. 258) at 16; *see also id.* at 30

("Activision's Accused Games can perform other 'compare,' 'store,' or 'combine' steps not required by the claims in any order without altering the fact that those games infringe."). Plaintiffs argue that there is at least one final combining step that begins after each light source has been compared and stored, and thus the fact that there may be intermediate combining steps before the comparing and storing steps are completed is irrelevant.

In support of this argument, Plaintiffs primarily rely on the word "comprising" in the preamble of claim 1 of the '822 patent and the '488 patent, and Federal Circuit precedent that "comprising" indicates an open claim creating "a presumption that the recited elements are only a part of the device, that the claim does not exclude additional, unrecited elements." *Crystal Semiconductor Corp. v. TriTech Microelectronics Int'l, Inc.*, 246 F.3d 1336, 1348 (Fed. Cir. 2001). Plaintiffs also point to the report of their expert, Dr. Aliaga, who opines that "only the steps used to show infringement by the Accused Games must follow the order of steps from the Asserted Patents." Resp. (ECF No. 258) at 16.

Because Plaintiffs do not dispute the facts underlying Activision's argument, this is a legal issue to be resolved by the Court: do the '822 and '488 patents require that comparing and storing be completed for each light source before any combining begins? Or, put differently, can the accused games perform other "compare," "store," and "combine" steps—not relied on to show infringement—in any order, without impacting whether the accused games infringe the asserted claims?

The Court concludes that because the Court's construction requires that the comparing and storing steps are completed *before beginning* the combining step, the accused games do not infringe the asserted claims because the undisputed evidence shows that combining steps begin before the comparing and storing steps are completed for each light source.

The Court is not persuaded that the word "comprising" in the preamble of the asserted method claims—claim 1 of the '822 patent and claim 1 of the '488 patent—gives Plaintiffs license to disregard other comparing, storing, and combining steps performed by the accused games when showing infringement. While "[i]t is true that a method claim with the word 'comprising' appearing at the beginning generally allows for additional, unclaimed steps in the accused process, . . . *each claimed step must nevertheless be performed as written*." *David Netzer Consulting Eng'r LLC v. Shell Oil Co*., 824 F.3d 989, 998 (Fed. Cir. 2016) (emphasis added). The Federal Circuit has stated that "comprising" "is not a weasel word with which to abrogate claim limitations," *Spectrum Int'l, Inc. v. Sterilite Corp*., 164 F.3d 1372, 1380 (Fed. Cir. 1998), and clarified the impact of the word "comprising" in method claims as follows:

> "Comprising" appears at the beginning of the claim—"comprising the steps of"—and indicates here that an infringing process could practice other steps in addition to the ones mentioned. *Those six enumerated steps must, however, all be practiced as recited in the claim for a process to infringe.* The presumption raised by the term "comprising" does not reach into each of the six steps to render every word and phrase therein open-ended—especially where, as here, the patentee has narrowly defined the claim term it now seeks to have broadened.

Dippin' Dots, Inc. v. Mosey, 476 F.3d 1337, 1343 (Fed. Cir. 2007) (emphasis added).

Here, "comparing," "storing," and "combining" are enumerated steps, recited in the claim. They are not "unrecited elements" which can be practiced in addition to the enumerated steps; they *are* the recited, enumerated steps, which the Court has construed as being performed in a specific and particular order. *See Crystal Semiconductor*, 246 F.3d at 1351 ("comprising" encompasses additional unrecited elements, "unless the written description or the prosecution history clearly limits [the claim] to its recited elements"); *Nat'l Oilwell Varco, L.P. v. Omron Oilfield & Marine, Inc*., 2013 WL 8508579, at *7 (W.D. Tex. Aug. 30, 2013) ("[t]he open-ended transition 'comprising' does not free the claim from its own limitations." (quoting *Kustom Signals, Inc. v. Applied Concepts, Inc*., 264 F.3d 1326, 1333 (Fed. Cir. 2001).). Thus, to

infringe, the accused games must perform the comparing, storing, and combining steps as recited in the claims and construed by the Court.

The Court's construction is clear that "the comparing and storing steps are completed before beginning the combining step"—not that *some* of the comparing and storing steps must be completed before beginning the combining step, or that the comparing and storing steps are completed before beginning *a* combining step. To conclude that the word "comprising" in the preamble empowers Plaintiffs to pick and choose which comparing, storing, and combining steps are used to show infringement would render the Court's construction superfluous. Moreover, such a construction would undermine the notice function of the claims, because it would preclude competitors seeking to design around Plaintiffs' invention from knowing the actual scope of the claims, and allow Plaintiffs to benefit from the ambiguity. *See Halliburton Energy Servs., Inc. v. M-I LLC*, 514 F.3d 1244, 1253–54 (Fed. Cir. 2008).

At minimum, Plaintiffs have not shown infringement of claim 27 of the '488 patent, which does not use the word "comprising." Plaintiffs argue that language like "at least" in claim 27 has the same effect as "comprising" in creating an open claim, but provide no authority interpreting "at least" to have the same presumptive effect as "comprising." Moreover, the plain text of claim 27 does not support reading "at least" to mean that the entire claim is open; on the contrary, "at least" is used only with specific claim elements (*e.g.*, "at least one set of computer instructions," "at least one processor," etc.), and the claim as a whole reads as though the "steps" to be performed are fixed and closed. *See* '488 patent, cl. 27 ("A computer-readable medium . . . configured to cause at least one processor to operatively render simulated shadows . . . by performing the steps of: . . . .").

Accordingly, because the Court's claim construction requires that the comparing and storing steps are completed for each light source before beginning the combining step, and it is undisputed that the accused games perform combining steps prior to the completion of the comparing and storing steps, the accused games do not infringe the asserted claims. Summary judgment of noninfringement is granted on this additional basis.

IV. Activision's Motion to Exclude the Opinions of Plaintiffs' Damages Expert Lance Gunderson and Technical Expert Daniel Aliaga

Activision moves to strike the expert opinions of Plaintiffs' damages expert, Lance Gunderson, and technical expert, Dr. Daniel Aliaga. Because the Court concludes that the sole damages theory put forth by Gunderson is insufficiently tied to the facts of the case, the Court grants Activision's motion to strike Gunderson's report. The Court denies the remainder of the motion as moot in light of the Court's decision to grant of summary judgment of noninfringement.

a. Legal Standard

Under Federal Rule of Evidence 702, a witness who is qualified as an expert may testify in the form of an opinion or otherwise if (1) the expert's specialized knowledge will help the trier of fact to understand the evidence or determine a fact in issue, (2) the testimony is based on sufficient facts or data, (3) the testimony is the product of reliable principles and methods, and (4) the expert has reliably applied the principles and methods to the facts of the case. When evaluating a party's challenge to an opponent's expert witness, the Court assumes the role of gatekeeper to ensure the relevance and reliability of the expert's testimony. *Daubert v. Merrell Dow Pharms., Inc.*, 509 U.S. 579, 597 (1993). Reliable testimony must be grounded "in the methods and procedures of science" and signify knowledge beyond "subjective belief or unsupported speculation." *Id.* at 590. The proponent of expert testimony must establish its

reliability by a preponderance of the evidence. *Bourjaily v. United States*, 483 U.S. 171, 174–76 (1987). However, the question of whether the expert is credible, or the opinion is correct, is generally a question for the fact finder, not the court. *See Summit 6, LLC v. Samsung Elecs. Co.*, 802 F.3d 1283, 1296 (Fed. Cir. 2015).

b. Damages Opinion of Lance Gunderson

Damages for patent infringement are governed by 35 U.S.C. § 284, which provides, in pertinent part, that "the court shall award the claimant damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer." 35 U.S.C. § 284. The patentee bears the burden of proving damages. *Dow Chem. Co. v. Mee Indus., Inc.*, 341 F.3d 1370, 1372, 1381 (Fed. Cir. 2003). "To be admissible, expert testimony opining on a reasonable royalty must 'sufficiently [tie the expert testimony on damages] to the facts of the case. If the patentee fails to tie the theory to the facts of the case, the testimony must be excluded.'" *Exmark Mfg. Co. v. Briggs & Stratton Power Prods. Grp., LLC*, 879 F.3d 1332, 1349 (Fed. Cir. 2018) (alteration in original) (quoting *Uniloc USA, Inc. v. Microsoft Corp.*, 632 F.3d 1292, 1315 (Fed. Cir. 2011)).

Gunderson, Plaintiffs' damages expert, opines that following a hypothetical negotiation based on an analysis of the factors articulated in *Georgia-Pacific Corp. v. U.S. Plywood Corp.*, 318 F. Supp. 1116, 1120 (S.D.N.Y. 1970), the parties would have agreed to a running royalty based on sales of the accused games. Gunderson provides two damages figures: one based on domestic sales of the accused games, and an alternative calculation based on foreign sales. Gunderson's damages theory does not apportion damages on a patent-by-patent basis or between the method and apparatus claims.

Activision moves to strike Gunderson's reasonable royalty analysis and damages opinions on the grounds that Gunderson does not identify a nexus between the alleged infringement of the method claims and sales, does not apportion damages between the alleged infringement of the method claims and the apparatus claim, the hypothetical negotiation date is not supported by the evidence, the licensing agreements relied on by Gunderson are not comparable, and Gunderson improperly relies on privileged communications and documents not produced in discovery to reach his proposed royalty rate. Activision further argues that Gunderson's testimony regarding foreign sales should be excluded because Plaintiffs cannot recover for sales of the accused games outside of the United States.

The Court concludes that Gunderson does not show a nexus between sales of the accused game and performance of the asserted method claims. For the method claims—claim 1 of the '822 patent and claim 1 of the '488 patent—Plaintiffs' direct infringement allegations rely on internal testing of the accused games by Activision before release, and demonstrations of the accused games at public gaming events, such as conferences. *See* Gunderson Rep. ¶¶ 30–35 (Def.'s Appx6–10) (ECF No. 272). Gunderson's opinion regarding damages relies entirely on sales of the accused games: he opines that based on the *Georgia-Pacific* factors, following a hypothetical negotiation the parties would have agreed to "a royalty rate between 1% to 2% applied to Accused Games revenue." *Id.* ¶ 168 (Appx28).

However, "method claims are 'not directly infringed by the mere sale of an apparatus capable of performing the claimed process.'" *Packet Intel. LLC v. NetScout Sys., Inc.*, 965 F.3d 1299, 1314 (Fed. Cir. 2020) (quoting *Joy Techs., Inc. v. Flakt, Inc.*, 6 F.3d 770, 773 (Fed. Cir. 1993)). One "cannot simply count sales of the [product] accused of infringing the [asserted] patent as sales of the method claimed." *Id.* Instead, the damages base must be "tailored to any

alleged internal use of the claimed methods." *Id.*; *ResQNet.com, Inc. v. Lansa, Inc.*, 594 F.3d 860, 869 (Fed. Cir. 2010) ("[T]he damages inquiry must concentrate on compensation for the economic harm caused by infringement of the claimed invention.").

Here, Gunderson does not analyze the economic harm of the alleged use of the claimed methods during game testing and development or during game demonstrations, and makes no effort to tie the claimed damages base to Activision's internal use of the patented method. Instead of determining how many sales of the accused games were based on use of the method, Gunderson seemingly assumes that assumes that all sales of the accused games are attributable to Activision allegedly performing the claimed method internally during testing and demonstrations. Accordingly, Gunderson's damages opinions are not sufficiently tied to the facts of the case, warranting exclusion.

Plaintiffs point to *Carnegie Mellon University. v. Marvell Technology Group, Ltd.*, 890 F. Supp. 2d 602, 610 (W.D. Pa. 2012), *aff'd in part, rev'd in part, vacated in part*, 807 F.3d 1283 (Fed. Cir. 2015), for the proposition that sales of a product may be an appropriate measure of damages resulting from internal use of a patented method. The Court agrees that, in some instances, it may be appropriate to base damages for internal use of a claimed method on product sales. But, as explained by the Federal Circuit in *Packet Intelligence*, to do so there must be some connection between the accused infringer's use of the method and subsequent sales. *See* 965 F.3d at 1314.

On that point, *Carnegie Mellon* is distinguishable from the facts presented here. There, the district court acknowledged "one of the simplest ways to determine the value of an infringing use of a patented method during research is to ascertain how many sales were made based on that infringing use." 890 F. Supp. 2d at 610. The evidence presented at summary judgment showed

that the accused infringer infringed the claimed method by using the accused programs and chips "throughout its sales cycle," including by providing samples to potential customers and adjusting the design internally in response to customer feedback. *Id.* at 604–05. Moreover, the accused infringer "conceded that its infringing use *is the but-for cause of [its] sales*." *Id.* at 610 (emphasis added). Thus, in *Carnegie Mellon* there was a clear nexus between internal use of the patented method and sales, which is wholly absent here.

Plaintiffs also point to portions of Gunderson's and Dr. Aliaga's reports discussing the importance of Activision's internal testing and demonstrations, which Plaintiffs posit show a connection between testing and demonstrations using the patented method of deferred rendering and sales of the accused games. *See* Pls.' Resp. (ECF No. 288) at 13–15 (citing Gunderson Rep. ¶¶ 14, 30–35, and Aliaga Rep. ¶¶ 714–15). Plaintiffs cite Paragraphs 14 and 30–35 of Gunderson's report, which discuss video game testing generally, and the importance of testing some of the accused games to ensure quality, compatibility with different gaming systems and consoles, and to minimize bugs and other defects. Plaintiffs also point to Paragraphs 714 and 715 of Dr. Aliaga's report, in which he opines that "[w]ithout such testing done during development to ensure the games going out the door are polished and playable and post-production testing of the game engine, the overall success of the game would be negatively impacted as the games would present various glitches and, in some circumstances, would not even be functional." Aliaga Rep. ¶ 714 (ECF No. 289), Appx. 101.

The Court disagrees with Plaintiffs' argument. This evidence does not show a nexus or connection between Activision's performance of the claimed method and sales. There is no mention in these cited paragraphs of deferred rendering, image quality, light sources, or anything relating specifically to the claimed method. At most, Plaintiffs' evidence establishes that testing

games before release is generally important to game development. However, Plaintiffs' evidence does not establish that testing affects sales; Gunderson's report focuses on testing as a means to ensure the quality of the games being produced, but does not tie increasing game quality to an impact on sales. And while Dr. Aliaga opines that failure to test would negatively impact a game's success, he does not state the inverse—*i.e.*, that testing positively impacts sales, and if so, how. More importantly, neither Gunderson nor Dr. Aliaga identify any connection between internal use of the claimed method specifically—be it through testing or demonstrations—and sales.

Because there is no evidence that sales were made based on infringing use of the claimed methods, Gunderson's damages model, which relies entirely on sales of the accused games, is not tailored to any alleged internal use of the claimed method. Moreover, because Gunderson presents a unitary damages theory and does not indicate which portion of his proposed royalty is based on alleged infringement of the method claims versus the asserted apparatus claim (claim 27 of the '488 patent), his entire testimony must be excluded. Because this deficiency is dispositive as to Gunderson's testimony, the Court does not reach the other deficiencies urged in Activision's Motion to Strike his testimony. Accordingly, the Court grants Activision's Motion to Exclude the Opinions of Plaintiffs' Damages Expert Lance Gunderson.

V. Conclusion

For the foregoing reasons, Activision's Motion for Summary Judgment of Noninfringement is **GRANTED**. The Court grants summary judgment that Activision does not infringe claim 1 of the '822 patent and claims 1 and 27 of the '488 patent. Summary judgment is denied on all other grounds. In addition, Activision's Motion to Exclude the Opinions of Plaintiffs' Damages Expert Lance Gunderson is **GRANTED**.

Plaintiffs' Motion for Partial Summary Judgment of No Invalidity, Activision's Motion to Exclude the Opinions of Technical Expert Daniel Aliaga, Plaintiffs' Motion to Strike Portions of Dr. Scott Schaefer's Expert Report Regarding Invalidity, and Plaintiffs' Motion to Strike Portions of Anthony J. Pelham's Expert Report Regarding Invalidity are **DENIED AS MOOT**. All remaining deadlines in the Court's scheduling order (ECF No. 257) are vacated.

The Court will enter a separate final judgment.

SO ORDERED.

September 16, 2021.

Barbara M G Lynn

BARBARA M. G. LYNN
CHIEF JUDGE

**IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF TEXAS
DALLAS DIVISION**

INFERNAL TECHNOLOGY, LLC AND TERMINAL REALITY, INC., *Plaintiffs*,	
v.	Case No. 3:18-cv-1397-M
ACTIVISION BLIZZARD INC., *Defendant.*	

CLAIM CONSTRUCTION MEMORANDUM OPINION AND ORDER

This Order addresses the claim-construction disputes jointly presented by the parties in *Infernal Technology, LLC et al. v. Microsoft Corp.*, No. 2:18-cv-00144-JRG (E.D. Tex.) (the "Microsoft Case"), *Infernal Technology, LLC et al. v. Crytek GmbH*, No. 2:18-cv-00284-JRG (E.D. Tex.) (the "Crytek Case"), and *Infernal Technology, LLC et al. v. Activision Blizzard Inc.*, No. 3:18-cv-01397-M (N.D. Tex.) (the "Activision Case"). The parties submitted the same claim-construction briefing in all cases. Infernal Technology, LLC and Terminal Reality, Inc. (collectively, "Plaintiffs") submitted opening and responsive briefs (Microsoft Case, Dkt. No. 101 and Dkt. No. 107; Crytek Case, Dkt. No. 45 and Dkt. No. 47; Activision Case, Dkt. No. 93 and Dkt. No. 96). Microsoft Corp., Crytek GmbH, and Activision Blizzard Inc. (collectively "Defendants") submitted opening and responsive briefs (Microsoft Case, Dkt. No. 99 and Dkt. No. 106; Crytek Case, Dkt. No. 43 and Dkt. No. 46; Activision Case, Dkt. No. 90 and Dkt. No. 95). The U.S. District Courts for the Northern District of Texas and the Eastern District of Texas held a concurrent claim-construction hearing in these proceedings on August 16, 2019. Having considered the arguments and evidence presented by the parties at the hearing and in their briefing, the Court issues this Order.

Table of Contents

I. BACKGROUND

Plaintiffs allege infringement of two U.S. Patents: No. 6,362,822 (the "'822 Patent") and No. 7,061,488 (the "'488 Patent") (collectively, the "Asserted Patents"). The application that issued as the '488 Patent is a continuation of the application that issued as the '822 Patent, which was filed on March 12, 1999. Each of the Asserted Patents is entitled "Lighting and Shadowing Method and Arrangements for Use in Computer Graphic Simulations."

The Asserted Patents were construed previously in *Infernal Technology, LLC et al. v. Electronic Arts Inc.*, No. 2:15-cv-1523-JRG-RSP (E.D. Tex.) (the "EA Case"). The EA Court issued a claim-construction order on September 27, 2016. 2016 WL 5415429 (the "*EA Construction*"). Several of the terms in dispute here were addressed in, or include terms addressed in, the *EA Construction*.

Each of the Asserted Patents was also the subject of Inter Partes Review before the U.S. Patent and Trademark Office in IPR2016-00928 (the "'822 Patent IPR") and consolidated IPR2016-00929 and IPR2016-00930 (the "'488 Patent IPR").[1] The Patent Trial and Appeal Board ("PTAB") issued decisions instituting review of the Asserted Patents in October 2016[2] and issued final written decisions declining to invalidate any claims of the patents in October 2017.[3] In the institution decisions, as relevant here, the PTAB provided a preliminary claim-construction

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[1] The parties provide select excerpts from various IPR papers as exhibits. The complete papers are available to the public through the U.S. Patent and Trademark Office's Patent Trial and Appeal Board End to End System at https://ptab.uspto.gov/#/login.

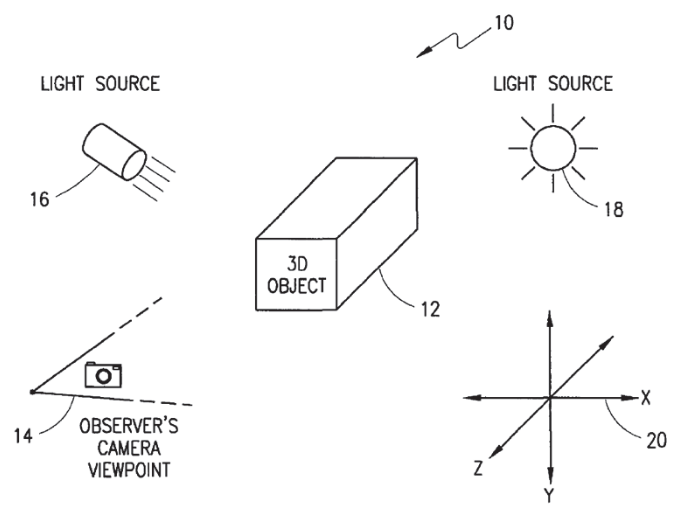
[2] *Electronic Arts et al. v. Terminal Reality, Inc.*, IPR2016-00928, paper 7, 2016 WL 7093913 (PTAB Oct. 25, 2016) ("*'822 Patent IPR Institution*"); *Electronic Arts et al. v. Terminal Reality, Inc.*, IPR2016-00929, paper 7, 2016 WL 7093937 (PTAB Oct. 25, 2016) ("*'488 Patent IPR Institution*").

[3] *Electronic Arts et al. v. Terminal Reality, Inc.*, IPR2016-00928, paper 48, 2017 WL 4805200 (PTAB Oct. 23, 2017) ("*'822 Patent IPR Final*"); *Electronic Arts et al. v. Terminal Reality, Inc.*, IPR2016-00929, paper 50, 2017 WL 4764807 (PTAB Oct. 19, 2017) ("*'488 Patent IPR Final*").

analysis of "light accumulation buffer." *'822 Patent IPR Institution*, slip op. at 11–15; *'488 Patent IPR Institution,* slip op. at 12–15.

In general, the Asserted Patents are directed to technology for handling lighting and shadowing in computer graphics. The technology can be generally understood with reference to Figures 2, 3, and 4 of the '822 Patent.[4] Figure 2, reproduced here, depicts a simulated three-dimensional ("3D") scene (10). The scene includes at least one 3D object (12) that is represented by spatial data, such as polygons. And the scene is illuminated by one or more light sources (16, 18). The 3D scene is rendered in two dimensions ("2D") and the 2D image is suitable for display, such as on a computer screen. The 2D view of the 3D scene is from the observer's, or camera's (14), perspective and takes into account the light incident on the 3D object as viewed from the observer's perspective. The relative positions of the object, observer, and light sources are defined using a 3D coordinate system (20). '822 Patent col.1 ll.25–38, col.6 ll.28–57.

'822 Patent Figure 2



Figures 3 and 4, reproduced below, depict exemplary data structures and an image processing flow for producing an image for display. The scene is rendered into 2D from the observer's (camera's) view (step 102) and also from each light source's view (step 104). The 2D data for each view include image (e.g., color) and depth information associated with each point in the view's

[4] The disclosures of the '822 Patent and the '488 Patent are substantially the same. As such, the Court cites the '822 Patent, understanding that the cited material is also in the '488 Patent.

2D coordinate system (data structures 51A, 51B, 51C, 51D, 51E, 51F). The 2D version of the scene from the observer's view is transformed from the observer's coordinate system to the light source's coordinate system (step 106) and for each region in the observer's view that is illuminated by the light source, the light image information is accumulated in a light source buffer (data structure 51G) (step 108). After the observer data is processed for each light source to generate the accumulated light data, the accumulated light data is combined with the observer data to generate the image for display (data structure 50; step 118). *Id*. at col.6 l.58 – col.9 l.22.

'822 Patent

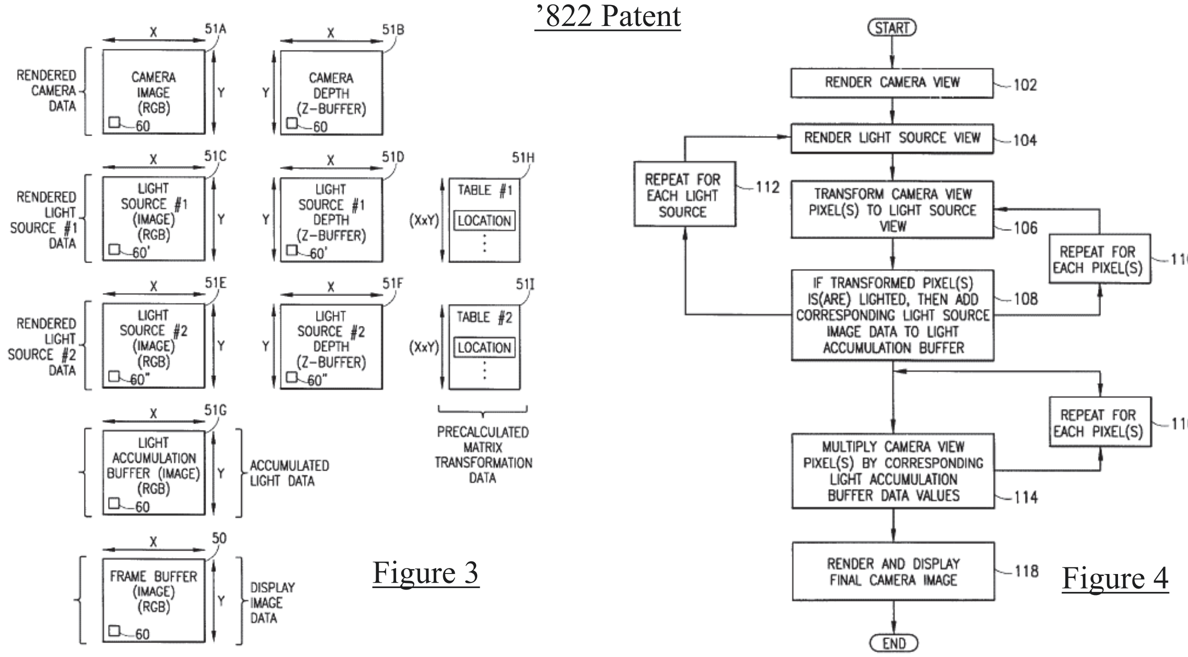


Figure 3

Figure 4

The abstracts of the Asserted Patents are identical and provide:

> The effects of lighting and resulting shadows within a computer simulated three-dimensional scene are modeled by rendering a light depth image and a light color image for each of the light sources. The light depth images are compared to a camera depth image to determine if a point within the scene is lighted by the various light sources. An accumulated light image is produced by combining those portions of the light color images determined to be lighting the scene. The resulting accumulated light image is then combined with a camera color image to produce a lighted camera image that can be further processed and eventually displayed on a computer display screen. The light color image can be static or dynamic. Transformations between different perspective and/or coordinate systems can be precalculated for fixed cameras or light sources. The various images and

manipulations can include individual pixel data values, multiple-pixel values, polygon values, texture maps, and the like.

Claim 1 of the ’822 Patent and Claim 11 of the ’488 Patent, exemplary method and system claims respectively, recite as follows:

’822 Patent Claim 1:

A shadow rendering method for use in a computer system, the method comprising the steps of:

providing observer data of a simulated multi-dimensional scene;

providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;

for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in a light accumulation buffer; and then

combining at least a portion of said light accumulation buffer with said observer data; and

displaying resulting image data to a computer screen.

’488 Patent Claim 11:

An arrangement configured to render shadows in a simulated multi-dimensional scene, the arrangement comprising:

an output to a display screen configured to display image data;

memory for storing data including observer data associated with a simulated multi-dimensional scene, and lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data, said memory further including a light accumulation buffer portion and a frame buffer portion;

at least one processor coupled to said memory and said output and operatively configured to, for each of said plurality of light sources, compare at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in said light accumulation buffer, then combining at least a portion of said light accumulation buffer with said observer data, and storing resulting image data in said frame buffer, and outputting at least a portion of said image data in said frame buffer via said output.

Plaintiffs allege that Activision has infringed Claims 1–9 of the ’822 Patent and Claims 1–9 and 27–36 of the ’488 Patent by making, using, and selling certain video games and by inducing others to use the games. (Dkt. No. 101 at 11–12.)

II. LEGAL PRINCIPLES

A. Claim Construction

“It is a ‘bedrock principle’ of patent law that ‘the claims of a patent define the invention to which the patentee is entitled the right to exclude.’” *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312 (Fed. Cir. 2005) (en banc) (quoting *Innova/Pure Water Inc. v. Safari Water Filtration Sys., Inc.*, 381 F.3d 1111, 1115 (Fed. Cir. 2004)). To determine the meaning of the claims, courts start by considering the intrinsic evidence. *Id.* at 1313; *C.R. Bard, Inc. v. U.S. Surgical Corp.*, 388 F.3d 858, 861 (Fed. Cir. 2004); *Bell Atl. Network Servs., Inc. v. Covad Commc’ns Group, Inc.*, 262 F.3d 1258, 1267 (Fed. Cir. 2001). The intrinsic evidence includes the claims themselves, the specification, and the prosecution history. *Phillips*, 415 F.3d at 1314; *C.R. Bard, Inc.*, 388 F.3d at 861. The general rule—subject to certain specific exceptions discussed *infra*—is that each claim term is construed according to its ordinary and accustomed meaning as understood by one of ordinary skill in the art at the time of the invention in the context of the patent. *Phillips*, 415 F.3d at 1312–13; *Alloc, Inc. v. Int’l Trade Comm’n*, 342 F.3d 1361, 1368 (Fed. Cir. 2003); *Azure Networks, LLC v. CSR PLC*, 771 F.3d 1336, 1347 (Fed. Cir. 2014) (“There is a heavy presumption that claim terms carry their accustomed meaning in the relevant community at the relevant time.”) (vacated on other grounds).

“The claim construction inquiry … begins and ends in all cases with the actual words of the claim.” *Renishaw PLC v. Marposs Societa’ per Azioni*, 158 F.3d 1243, 1248 (Fed. Cir. 1998). “[I]n all aspects of claim construction, ‘the name of the game is the claim.’” *Apple Inc. v. Motorola, Inc.*, 757 F.3d 1286, 1298 (Fed. Cir. 2014) (quoting *In re Hiniker Co.*, 150 F.3d 1362, 1369 (Fed.

Cir. 1998)). First, a term's context in the asserted claim can be instructive. *Phillips*, 415 F.3d at 1314. Other asserted or unasserted claims can also aid in determining the claim's meaning, because claim terms are typically used consistently throughout the patent. *Id.* Differences among the claim terms can also assist in understanding a term's meaning. *Id*. For example, when a dependent claim adds a limitation to an independent claim, it is presumed that the independent claim does not include the limitation. *Id*. at 1314–15.

"[C]laims 'must be read in view of the specification, of which they are a part.'" *Id*. (quoting *Markman v. Westview Instruments, Inc.*, 52 F.3d 967, 979 (Fed. Cir. 1995) (en banc)). "[T]he specification 'is always highly relevant to the claim construction analysis. Usually, it is dispositive; it is the single best guide to the meaning of a disputed term.'" *Id*. (quoting *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1582 (Fed. Cir. 1996)); *Teleflex, Inc. v. Ficosa N. Am. Corp.*, 299 F.3d 1313, 1325 (Fed. Cir. 2002). But, "'[a]lthough the specification may aid the court in interpreting the meaning of disputed claim language, particular embodiments and examples appearing in the specification will not generally be read into the claims.'" *Comark Commc'ns, Inc. v. Harris Corp.*, 156 F.3d 1182, 1187 (Fed. Cir. 1998) (quoting *Constant v. Advanced Micro-Devices, Inc.*, 848 F.2d 1560, 1571 (Fed. Cir. 1988)); *see also Phillips*, 415 F.3d at 1323. "[I]t is improper to read limitations from a preferred embodiment described in the specification—even if it is the only embodiment—into the claims absent a clear indication in the intrinsic record that the patentee intended the claims to be so limited." *Liebel-Flarsheim Co. v. Medrad, Inc.*, 358 F.3d 898, 913 (Fed. Cir. 2004).

The prosecution history is another tool to supply the proper context for claim construction because, like the specification, the prosecution history provides evidence of how the U.S. Patent and Trademark Office ("PTO") and the inventor understood the patent. *Phillips*, 415 F.3d at 1317.

However, "because the prosecution history represents an ongoing negotiation between the PTO and the applicant, rather than the final product of that negotiation, it often lacks the clarity of the specification and thus is less useful for claim construction purposes." *Id.* at 1318; *see also Athletic Alternatives, Inc. v. Prince Mfg.*, 73 F.3d 1573, 1580 (Fed. Cir. 1996) (ambiguous prosecution history may be "unhelpful as an interpretive resource").

Although extrinsic evidence can also be useful, it is "'less significant than the intrinsic record in determining the legally operative meaning of claim language.'" *Phillips*, 415 F.3d at 1317 (quoting *C.R. Bard, Inc.*, 388 F.3d at 862). Technical dictionaries and treatises may help a court understand the underlying technology and the manner in which one skilled in the art might use claim terms, but technical dictionaries and treatises may provide definitions that are too broad or may not be indicative of how the term is used in the patent. *Id*. at 1318. Similarly, expert testimony may aid a court in understanding the underlying technology and determining the particular meaning of a term in the pertinent field, but an expert's conclusory, unsupported assertions as to a term's definition are not helpful to a court. *Id*. Extrinsic evidence is "less reliable than the patent and its prosecution history in determining how to read claim terms." *Id*. The Supreme Court has explained the role of extrinsic evidence in claim construction:

> In some cases, however, the district court will need to look beyond the patent's intrinsic evidence and to consult extrinsic evidence in order to understand, for example, the background science or the meaning of a term in the relevant art during the relevant time period. *See, e.g., Seymour v. Osborne*, 11 Wall. 516, 546 (1871) (a patent may be "so interspersed with technical terms and terms of art that the testimony of scientific witnesses is indispensable to a correct understanding of its meaning"). In cases where those subsidiary facts are in dispute, courts will need to make subsidiary factual findings about that extrinsic evidence. These are the "evidentiary underpinnings" of claim construction that we discussed in *Markman*, and this subsidiary factfinding must be reviewed for clear error on appeal.

Teva Pharm. USA, Inc. v. Sandoz, Inc., 135 S. Ct. 831, 841 (2015).

B. Departing from the Ordinary Meaning of a Claim Term

There are "only two exceptions to [the] general rule" that claim terms are construed according to their plain and ordinary meaning: "1) when a patentee sets out a definition and acts as his own lexicographer, or 2) when the patentee disavows the full scope of the claim term either in the specification or during prosecution."[5] *Golden Bridge Tech., Inc. v. Apple Inc.*, 758 F.3d 1362, 1365 (Fed. Cir. 2014) (quoting *Thorner v. Sony Computer Entm't Am. LLC*, 669 F.3d 1362, 1365 (Fed. Cir. 2012)); *see also GE Lighting Solutions, LLC v. AgiLight, Inc.*, 750 F.3d 1304, 1309 (Fed. Cir. 2014) ("[T]he specification and prosecution history only compel departure from the plain meaning in two instances: lexicography and disavowal."). The standards for finding lexicography or disavowal are "exacting." *GE Lighting Solutions*, 750 F.3d at 1309.

To act as his own lexicographer, the patentee must "clearly set forth a definition of the disputed claim term," and "clearly express an intent to define the term." *Id.* (quoting *Thorner*, 669 F.3d at 1365); *see also Renishaw*, 158 F.3d at 1249. The patentee's lexicography must appear "with reasonable clarity, deliberateness, and precision." *Renishaw*, 158 F.3d at 1249.

To disavow or disclaim the full scope of a claim term, the patentee's statements in the specification or prosecution history must amount to a "clear and unmistakable" surrender. *Cordis Corp. v. Boston Sci. Corp.*, 561 F.3d 1319, 1329 (Fed. Cir. 2009); *see also Thorner*, 669 F.3d at 1366 ("The patentee may demonstrate intent to deviate from the ordinary and accustomed meaning of a claim term by including in the specification expressions of manifest exclusion or restriction, representing a clear disavowal of claim scope."). "Where an applicant's statements are amenable

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[5] Some cases have characterized other principles of claim construction as "exceptions" to the general rule, such as the statutory requirement that a means-plus-function term is construed to cover the corresponding structure disclosed in the specification. *See, e.g., CCS Fitness, Inc. v. Brunswick Corp.*, 288 F.3d 1359, 1367 (Fed. Cir. 2002).

to multiple reasonable interpretations, they cannot be deemed clear and unmistakable." *3M Innovative Props. Co. v. Tredegar Corp.*, 725 F.3d 1315, 1326 (Fed. Cir. 2013).

III. AGREED CONSTRUCTIONS

The parties have agreed to the following constructions set forth in their Joint Patent Rule 4-5(d) Claim Construction Chart (Dkt. No. 102).

Term[6]	Agreed Construction
"providing" • '822 Patent Claim 1 • '488 Patent Claims 1, 27	making available
"observer data of a simulated multi-dimensional scene" • '822 Patent Claim 1 • '488 Patent Claims 1, 27	data representing at least the color of objects in a simulated multi-dimensional scene as viewed from an observer's perspective
"observer data associated with a simulated multi-dimensional scene" • '488 Patent Claim 11	
"a modeled point within said scene" • '822 Patent Claims 1, 6 • '488 Patent Claims 1, 11, 27	a point on a modeled object within said scene
order of the comparing, storing, and combining steps • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	the comparing and storing steps are completed before beginning the combining step
"displaying resulting image data to a computer screen" • '822 Patent Claim 1	displaying the image data resulting from combining at least a portion of the light accumulation buffer with the observer data on a computer screen

[6] For all term charts in this order, the claims in which the term is found are listed with the term but: (1) only the highest-level claim in each dependency chain is listed, and (2) only asserted claims identified in the parties' Joint Patent Rule 4-5(d) Claim Construction Chart (Dkt. No. 102) are listed.

Term[6]	Agreed Construction
"outputting resulting image data" • '488 Patent Claims 1, 27	outputting for presentation to a user the image data resulting from combining at least a portion of the light accumulation buffer with the observer data
"combining at least a portion of said light accumulation buffer with said observer data" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	combining at least a portion of the data in the light accumulation buffer with said observer data • subject to having the terms (1) "at least a portion of," (2) "light accumulation buffer" and (3) "observer data" construed by the Court
"A computer-readable medium carrying at least one set of computer instructions configured to cause at least one processor to operatively render simulated shadows in a multidimensional simulated scene" • '488 Patent Claim 27	the preamble is limiting

Having reviewed the intrinsic and extrinsic evidence of record, the Court hereby adopts the parties' agreed constructions.

IV. CONSTRUCTION OF DISPUTED TERMS

A. The Preambles of Claim 1 of the '822 Patent and Claims 1 and 11 of the '488 Patent

Disputed Term	Plaintiffs' Proposed Construction	Defendants' Proposed Construction
"A shadow rendering method for use in a computer system" • '822 Patent Claim 1	the preamble is not limiting and no construction is necessary	the preamble is limiting
"A shadow rendering method" • '488 Patent Claim 1	the preamble is not limiting and no construction is necessary	the preamble is limiting

Because the parties' arguments and proposed constructions with respect to these terms are related, the Court addresses the terms together.

<u>The Parties' Positions</u>

Plaintiffs submit: The limitations recited in the bodies of Claim 1 of the '822 Patent and Claims 1 and 11 of the '488 Patent define structurally complete inventions without need for reference to the preambles. The preambles do not provide antecedent basis for any terms in the bodies of the claims and the preambles were not relied upon during prosecution of the Asserted Patents. Rather, the preambles simply provide an intended use or name for the limitations recited in the bodies of the claims. As such, the preambles are not limiting. (Dkt. No. 93 at 16–19, 31–32.)

Defendants submit: The preambles are limiting because they provide an important aspect of the inventions that is not apparent solely from the bodies of the claims; namely, that the claimed inventions are directed to improvements in shadow rendering in 3D computer graphics, and not simply to general lighting in 3D computer graphics. The Asserted Patents critique the shortcomings of prior-art shadow rendering and explain that the inventions are directed specifically to addressing these shortcomings with inventions based on additively lighting unshaded portions of objects (as opposed to the disparaged prior-art approach of additively darkening shaded objects). This was further explained by the patentee during inter partes review of the patents, where it represented that "the point of the invention is to render light and shadows." In other words, the claims are directed to "rendering the occlusion of modeled points from light sources … by other objects." This does not encompass simply determining whether a "light source is too far away from a given point to have any effect on it at all." (Dkt. No. 90 at 15–21.)

In addition to the claims themselves, Defendants cite the following intrinsic evidence to support their position: '822 Patent col.1 ll.57–59, col.2 ll.1–3, col.2 ll.7–10, col.2 ll.13–18, col.2 ll.36–38, col.2 ll.50–56, col.3 ll.8–9, col.7 ll.49–53, col.8 ll.62–67; James D. Foley et al., *Computer*

Graphics: Principles and Practice at 747 (2d ed. 1997) ("*Foley*") (Defendants' Ex. C, Dkt. No. 91 at 46–68); '822 Patent IPR Hr'g Tr.[7] at 44–45 (Defendants' Ex. J, Dkt. No. 91 at 199–204).

Plaintiffs respond: Defendants have not provided evidence sufficient to disregard the general rule that preambles are not limiting. The preambles state that shadow rendering is the intended purpose of the claimed invention but the claims define structurally complete methods for achieving this purpose. As explained in the Asserted Patents, the claims are directed to determining whether a modeled point is illuminated, and a point is "shaded" if it is not illuminated. This encompasses more than simply determining whether a point is occluded from the light source and indeed encompasses determining whether a light source is too far away to illuminate the point. (Dkt. No. 96 at 6–15.)

Plaintiffs cite further intrinsic evidence to support their position: '822 Patent, at [54] Title, [57] Abstract, col.1 ll.6–16, col.2 ll.15–16, col.3 ll.6–35, col.4 ll.20–24, col.7 ll.43–52, col.8 ll.57–63, col.12 ll.13–15.

Defendants respond: The Asserted Patents explain that shadow rendering is what the inventor actually invented and intended to cover with the claims. The preambles in the claims at issue are limiting because they recite "an essential characteristic of the system that informs the remainder of the claim." Specifically, the claims require "that the image ultimately output for display must include shadows rendered by the preceding steps." (Dkt. No. 95 at 7–12.)

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[7] Record of Oral Hearing Held July 18, 2017, *Electronic Arts et al. v. Terminal Reality, Inc.*, IPR2016-00928, Paper 47 (also addressing IPR2016-00929 and IPR2016-00930).

<u>Analysis</u>

The issue in dispute distills to whether the preambles' recitation of "shadow rendering" or "render shadows" should be construed to require the claims to include an occlusion limitation. They should not.

Under Federal Circuit precedent "a preamble is not limiting where a patentee defines a structurally complete invention in the claim body and uses the preamble only to state a purpose or intended use for the invention." *Acceleration Bay, LLC v. Activision Blizzard, Inc.*, 908 F.3d 765, 770 (Fed. Cir. 2018) (quotation marks and citations omitted). Likewise, a preamble is not limiting when it "merely gives a descriptive name to the set of limitations in the body of the claim that completely set forth the invention." *Am. Med. Sys. v. Biolitec, Inc.*, 618 F.3d 1354, 1359 (Fed. Cir. 2010). A preamble is limiting, however, when it is "necessary to give life, meaning, and vitality to the claim." *Catalina Mktg. Int'l v. Coolsavings.com, Inc.*, 289 F.3d 801, 808 (Fed. Cir. 2002) (quotation marks omitted). For example, "dependence on a particular disputed preamble phrase for antecedent basis may limit claim scope because it indicates a reliance on both the preamble and claim body to define the claimed invention." *Id*. "Likewise, when the preamble is essential to understand limitations or terms in the claim body, the preamble limits claim scope." *Id*. "Further, when reciting additional structure or steps underscored as important by the specification, the preamble may operate as a claim limitation." *Id*.

Here, the preambles do not add anything to the body of the claims. Each claim sets forth a complete method of lighting a scene in a way that will render shadows as appropriate and consistent with what the patentee described as the invention. Therefore, the preambles are not limiting.

The Court is not persuaded by Defendants' argument based on *Corning Glass Works v. Sumitomo Elec. U.S.A., Inc.*, 868 F.2d 1251 (Fed. Cir. 1989). In *Corning*, the body of the patent claim was directed to an optical fiber without any reference to the waveguide attributes of the invention. *Id*. at 1256. These waveguide attributes were specified in the patent as an important feature of the invention and required structural limitations on the fiber that were not apparent in the claim body. That is, the *Corning* invention was clearly an optical waveguide but the claim body gave no effect to the waveguide aspect of the invention. *Id*. at 1256–57. Thus, the preamble recitation of "optical waveguide" was limiting. *Id*. As set forth below, the claims at issue here are distinguishable from the claim in *Corning* because the claims here capture the key features of the invention in the bodies of the claims.

Here, the claims are analogous to the claim addressed in *Georgetown Rail Equip. Co. v. Holland L.P.*, 867 F.3d 1229 (Fed. Cir. 2017). The preamble of the claim at issue in *Georgetown* recited a "system for inspecting a railroad track bed, including the railroad track, to be mounted on a vehicle for movement along the railroad track." *Id*. at 1234. While the phrase "mounted on a vehicle for movement along the railroad track" was deemed by the Federal Circuit to describe the "principal intended use of the invention," it was held not limiting. *Id*. at 1236–37. The Federal Circuit held that the "location of the system is not an essential feature of the invention," as the patent provided that it may be located other than on the vehicle. *Id*. Thus, the preamble recitation of "mounted on a vehicle for movement along the railroad track" was not limiting.

Here, the bodies of the claims at issue capture the key aspects of the invention without reference to the preambles and therefore are more akin to the claim addressed in *Georgetown* than the claim addressed in *Corning*. The Asserted Patents are directed to technology for "rendering lighting and shadows in computer graphic simulations." '822 Patent col.1 ll.7–9; *see also*, *id*. at

col.3 ll.6–17 (“improved lighting and shadowing methods and arrangements are provided … [that] allow for multiple light sources to be modeled”). This is accomplished by accumulating light data for lit objects in the scene of the simulation. *See, e.g., id*. at col.3 ll.25–30. The technology may be used for rendering shadows as well as other lighting effects. For example, it “can also be used to simulate dynamically changing light sources, interrupted light beams, reflected light beams, and/or projected light images, such as, for example, motion picture, video, animation, and computer graphics images.” *Id*. at col.3 l.64 – col.4 l.2; *see also, id*. at col.10 l.63 – col.11 l.13 (noting that the invention may be used, e.g., “to simulate light that is reflected from changing surfaces, … [and] an animation, motion picture or similar video image that is projected”). In other words, there are a variety of intended uses for the invention. As in the *Georgetown* claim, the preambles here recite the primary intended use of the invention, namely, shadow rendering, but do not recite an essential feature of the invention. As the claims at issue here include bodies that define structurally complete inventions, the preambles each represent a nonlimiting statement of intended use.

Accordingly, the Court determines that the preambles of Claim 1 of the ’822 Patent and of Claims 1 and 11 of the ’488 Patent are not limiting.

B. “determine if a modeled point within said scene is illuminated by said light source”

Disputed Term	Plaintiffs’ Proposed Construction	Defendants’ Proposed Construction
“determine if a modeled point within said scene is illuminated by said light source” • ’822 Patent Claim 1 • ’488 Patent Claims 1, 11, 27	determining if a point on a modeled object within said scene is illuminated by said light source	calculate whether a modeled point is lighted by, or shaded from, said light source

<u>The Parties' Positions</u>

Plaintiffs submit: The words "determine" and "illuminated" are readily understood without construction and construing them as Defendants propose would improperly change the scope of the claims. Specifically, "determine" should not be rewritten as "calculate." The words either mean the same thing, in which case rewriting is unnecessary, or they mean different things, in which case rewriting is improper. Further, "illuminate" should not be rewritten as "lighted by, or shaded from." "Illuminated" is used in the Asserted Patents according to its plain meaning, i.e., "lit," and there is no support for injecting a "or shaded from" limitation into the construction. (Dkt. No. 93 at 24–26.)

In addition to the claims themselves, Plaintiffs cite the following intrinsic evidence to support their position: '822 Patent col.2 ll.15–18, col.8 ll.66–67.

Defendants submit: This limitation "refer[s] to an algorithm that calculates whether the point being modeled is shaded from the light source by another object in the scene." The Asserted Patents consistently and solely describe determining whether a point is illuminated as determining whether it "is lighted by, or shaded from, [the] light source" in the context of updating the light accumulation buffer if it is lit and not updating the buffer if the point "is not lighted (i.e., is shaded)" (quoting '822 Patent col.8 ll.62–67). Essentially, the point is illuminated if it is not shaded and determining whether it is illuminated requires determining whether it is shaded. As consistently and solely described in the patents, this is accomplished by comparing depth data for the point with that for the light source to determine if the point is hidden from the light source by another object (shaded). This is how Plaintiffs' experts in the EA Case and Inter Partes Reviews explained the determining step. Ultimately, calculating whether a point is lighted by or shaded

from the light source is "a fundamental characteristic of the invention" rather than an exemplary embodiment. (Dkt. No. 90 at 21–26.)

In addition to the claims themselves, Defendants cite the following intrinsic and extrinsic evidence to support their position: Intrinsic evidence: '822 Patent col.2 ll.36–56, col.3 ll.8–9, col.7 ll.26–29, col.7 ll.41–43, col.8 ll.62–67, col.9 ll.35–44; '822 Patent IPR Laub Decl. ¶¶ 41, 59 (Defendants' Ex. L, Dkt. No. 91 at 210–24). Extrinsic evidence: EA Case Ferraro Decl. ¶ 15 (Defendants' Ex. E, Dkt. No. 91 at 107–18).

Plaintiffs respond: The claims do not mention determining whether a point is shaded, only whether it is illuminated. The statements of Plaintiffs' expert in the '822 Patent IPR that Defendants rely on do not equate "determine if a modeled point … is illuminated by said light source" with "calculating whether a modeled point is lighted by, or shaded from, said light source." Rather, the expert provided an example of a situation when an object is not illuminated by a light source (a shaded object is not illuminated). Similarly, the statement of Plaintiffs' expert in the EA Case that Defendants rely on simply reflects that the claims require determining whether the point is illuminated. (Dkt. No. 96 at 15–19.)

Plaintiffs cite further intrinsic evidence to support their position: '822 Patent, at [57] Abstract.

Defendants respond: The Asserted Patents equate determining whether a point is illuminated with determining whether it is shaded. Thus, the "determine if a modeled point within said scene is illuminated by said light source" limitation does not encompass just any test for whether the source effects the point, "e.g., whether it is too far away." (Dkt. No. 95 at 13–15.)

Analysis

The issue in dispute is whether the "determine if a modeled point … is illuminated by said light source" limitation requires a calculation of whether the point is lighted by or shaded from the

light source. It does not. While a shaded point is not illuminated by a light source, there are other instances in which a point is not illuminated by a light source.

As set forth above in the section addressing the dispute as to the preambles, the Asserted Patents expressly state that the lighting and shading methods are applicable to modeling dynamically changing light sources that may variably illuminate, or not, a point in the scene without consideration of intervening objects that may shade the point from the light source. Thus, contrary to Defendants' contention, the Asserted Patents do not meet the exacting standard to redefine "illuminated" as "not shaded." Further, the patents specifically disclose directional light sources that may not illuminate a point by virtue of the direction. *See, e.g.*, '822 Patent col.6 ll.41–43 ("Light source #1, in this example, is a uni-directional light source having a particular position, orientation and constrained field-of-view."), col.10 ll.40–43 ("These light sources, which are not shown in FIG. 7C, are directional light sources having fixed positions with respect to room 200."). The patents provide that transformation between the light-source coordinate system and the observer (camera) coordinate system may determine whether the light from the light source illuminates a point. *See, e.g.*, *id*. at col.8 ll.9–11 ("Thus, the resulting transformation table #1 can be used to quickly ***determine which, if any, of pixels*** 60' (light image) correspond to a specific pixel 60 (camera image)." (emphasis added)). That is, light from the source is not added to the modeled point if it is not directed to the modeled point—the source does not illuminate the point when there is no overlap of the light image and the camera image. This is determined through the transformation between camera view and light-source view. *See also, id*. at col.11 ll.28–35 (noting a light source facing in a direction such as to not illuminate an object (man) in the scene).

Accordingly, the Court construes this term as follows:

- "determine if a modeled point within said scene is illuminated by said light source" means "determine if a point on a modeled object within said scene is illuminated by said light source."

C. "providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data"

Disputed Term	Plaintiffs' Proposed Construction	Defendants' Proposed Construction
"providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	"lighting data" should be construed to have its plain and ordinary meaning (i.e., "data relating to the representation of simulated light sources arranged to illuminate said scene")	Light image data is required for each of a plurality of light sources. "lighting data" means "2D color and depth data, for a plurality of simulated light sources"

<u>The Parties' Positions</u>

Plaintiffs submit: As explained in the Asserted Patents, "lighting data" is not limited to "2D color and depth data." Rather, 2D color and depth data is described as exemplary in the patents and appears expressly in dependent claims (e.g., '822 Patent Claim 4) indicating that "lighting data" is not inherently limited to 2D color and depth data. (Dkt. No. 93 at 19–22.)

In addition to the claims themselves, Plaintiffs cite the following **intrinsic evidence** to support their position: '822 Patent col.3 ll.36–51, col.6 ll.41–43, col.12 ll.32–37.

Defendants submit: The Asserted Patents provide that "lighting data" must include at least color data and depth data and that this data must be 2D data. Plaintiffs, and their experts, stated in the EA Case and in the '822 Patent IPR that "lighting data" necessarily includes 2D color data and depth data for a plurality of simulated light sources. In the '822 Patent IPR, Plaintiffs distinguished

prior art based on the fact that lighting data includes 2D color data and depth data. Finally, as explained in the patents and by Plaintiffs in the EA Case and in the ’822 Patent IPR, lighting data includes 2D color data and depth data for each of a plurality of light sources. (Dkt. No. 90 at 26–34.)

In addition to the claims themselves, Defendants cite the following intrinsic and extrinsic evidence to support their position: Intrinsic evidence: ’822 Patent figs.3–4, col.3 ll.41–51, col.4 ll.24–28, col.4 ll.55–56, col.6 l.58 – col.7 l.42, col.8 ll.42–44, col.9 ll.3–8, col.9 ll.31–34, col.10 ll.63–65; ’822 Patent IPR Patent Owner Preliminary Response at 7–8 (Defendants’ Ex. H, Dkt. No. 91 at 181–91), Patent Owner Response at 3–5 (Defendants’ Ex. I, Dkt. No. 91 at 192–98), Hrn’g Tr. at 36 (Defendants’ Ex. J, Dkt. No. 91 at 199–204), Laub Decl.[8] ¶¶ 56–57, 61, 78–79, 83–84 (Defendants’ Ex. L, Dkt. No. 91 at 210–24). Extrinsic evidence: EA Case Ferraro Decl.[9] ¶¶ 10, 12, 16 (Defendants’ Ex. E, Dkt. No. 91 at 107–18).

Plaintiffs respond: That lighting data is provided by each of a plurality of light sources is required by other claim language. Including a “for each of a plurality of light sources” limitation in the construction of “lighting data” therefore threatens to confuse rather than clarify claim scope. The 2D color and depth data described in the Asserted Patents is exemplary, not definitional. Specifically, the patents provide that “the data in the light image … can represent the intensity, color, and/or pattern of light emitted” (quoting ’822 Patent col.7 ll.32–34). Certain dependent claims (Claims 4, 14, and 42 of the ’822 Patent and Claims 4, 14, and 30 of the ’488 Patent) expressly require the “lighting data” to include source and color data so it would be improper to require “lighting data” to inherently include these limitations in the independent claims. The

[8] Declaration of Leonard Laub, IPR2016-00928, Exhibit 2008.
[9] Declaration of Richard F. Ferraro, EA Case, Dkt. No. 77-3.

statements by the experts in the EA Case and the ’822 Patent IPR that Defendants rely on are descriptions of lighting data in the context of the exemplary embodiment of Figure 3 of the patents and are not opinions on inherent characteristics of the claimed invention. Finally, the distinction between the claims and the prior art that was presented in the ’822 Patent IPR is that the prior art reference “does not teach that M1 is a look-up table that includes lighting data coordinates.” This is not a disclaimer that limits “lighting data” to 2D color and depth data. (Dkt. No. 96 at 19–25.)

Plaintiffs cite further intrinsic evidence to support their position: ’822 Patent fig.3, col.3 l.63 – col.4 l.5, col.5 ll.28–31, col.6 ll.38–48, col.6 ll.59–60, col.7 ll.32–34; ’822 Patent IPR Laub Decl. ¶ 151.[10]

Defendants respond: Plaintiffs argued in the EA Case that lighting data was 2D data and the EA Court accepted that position. As such, Plaintiffs are estopped from taking a different position here. Further, Plaintiffs’ expert in the EA Case stated that the “lighting data” of the invention is “2D color data and depth data for a plurality of simulated light sources.” Plaintiffs and their expert in the ’822 Patent IPR distinguished the lighting data of the Asserted Patents from that in the prior art on the ground that the prior art disclosed only depth data, and did not include illumination data. Plaintiffs also argued in the ’822 Patent IPR that the claimed invention is distinct over the prior art because it includes manipulation of 2D images. Finally, “lighting data” is used consistently in the patents to refer to data that includes at least “2D color data and depth data.” This mandates the conclusion that “2D color data and depth data” is not merely exemplary of the “lighting data” of

[10] Paragraph 151 of the Laub declaration was not submitted by the parties. The declaration is available to the public through the U.S. Patent and Trademark Office’s Patent Trial and Appeal Board End to End System at https://ptab.uspto.gov/#/login.

the patents, but rather is necessarily included in the "lighting data" of the patents. (Dkt. No. 95 at 15–23.)

Defendants cite further intrinsic and extrinsic evidence to support their position: Intrinsic evidence: '822 Patent IPR Patent Owner Preliminary Response at 1, 2, 5 (Defendants' Ex. H, Dkt. No. 91 at 181–91). Extrinsic evidence: EA Case Ferraro Decl. ¶ 17 (Defendants' Ex. E, Dkt. No. 91 at 107–18).

Analysis

There are two issues submitted to the Court, one of which is essentially undisputed: first, whether "lighting data" is necessarily provided for each of the plurality of light sources, and second, whether "lighting data" necessarily includes "2D color data and depth data." As for the first issue, lighting data is necessarily provided, but this is plainly expressed in the claims and is not in dispute. Therefore, this limitation does not need to be incorporated into a construction of "lighting data." As for the second issue, "lighting data" expressly includes "light image data," which, as explained below, necessarily includes 2D data. However, it does not necessarily include color and depth data. Therefore, "lighting data" does not need to be construed apart from "light image data."

The parties agree that lighting data is provided for each of a plurality of light sources. Since there is no dispute, there is no need for the court to issue a construction to resolve the dispute.

The patents do not teach that "lighting data" necessarily includes color and depth data. The independent claims at issue recite that lighting data includes light image data ("said lighting data including light image data") but otherwise do not specify the content of lighting data. The Asserted Patents provide that "***in certain embodiments***, the lighting data includes source color data associated with at least one of the light sources and source depth data associated with the plurality

of modeled polygons within the scene as rendered from a plurality of different light source's perspectives." '822 Patent col.3 ll.47–52 (emphasis added). Indeed, dependent Claim 4 of the '822 Patent is directed to such an embodiment: "said lighting data includes source color data associated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives." *Id*. at col.12 ll.32–37. This suggests that light-source color and depth data is not inherently included in "lighting data." *See Phillips v. AWH Corp.*, 415 F.3d 1303, 1314 (Fed. Cir. 2005) (en banc) (noting that the use of the term "steel baffles" "strongly implies that the term 'baffles' does not inherently mean objects made of steel"). Further, the Court is not persuaded by Defendants' argument that the description of the data structures of Figure 3 of the Asserted Patents mandates that lighting data must include 2D color and depth data. At the beginning of this description the patents provide: "FIG. 3 is a block diagram depicting ***exemplary arrangements*** of modeling data as used to render lighting and shadows, in accordance with ***certain embodiments*** of the present invention." *Id*. at col.6 ll.58–61 (emphasis added). That is, what Defendants proffer as definitional is expressly not definitional. To the extent Plaintiffs' expert in the EA Case offered any opinion that "lighting data" inherently includes color and depth data, that opinion is at odds with the intrinsic record. As such, rather than somehow being definitional of a claim term, as Defendants suggest, this testimony should be disregarded. *See Phillips v. AWH Corp.*, 415 F.3d 1303, 1318 (Fed. Cir. 2005) (en banc) ("a court should discount any expert testimony that is clearly at odds with the claim construction mandated by the claims themselves, the written description, and the prosecution history, in other words, with the written record of the patent" (quotation marks omitted)). The Court is also not persuaded that anything said by Plaintiffs or their expert in the

Inter Partes Reviews, as of record here, rises to the level of disclaimer that would require "lighting data" to necessarily include color and depth data.

As set forth below, the Court understands that "light image data" is necessarily two-dimensional (2D) data. Thus, "lighting data" necessarily includes 2D data because it expressly includes "light image data." Reflecting this in a construction of "lighting data," however, is unnecessary and potentially misleading. For example, it could suggest that "lighting data" necessarily includes data beyond "light image data," which is not the case.

Accordingly, the Court determines there is no dispute regarding whether there is lighting data for a plurality of simulated light sources, that "lighting data" does not inherently include color and depth data, and that the term has its plain and ordinary meaning and does not need to be otherwise construed apart from "light image data," which it expressly includes.

D. "light image data"

Disputed Term	Plaintiffs' Proposed Construction	Defendants' Proposed Construction
"light image data" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	for each of the plurality of light sources, data representing an image of the light emitted by the light source to illuminate the scene as viewed from the light source's perspective	for each of the plurality of light sources, pixel data values representing the light emitted by the light source to illuminate the scene as viewed from the light source's perspective

The Parties' Positions

Plaintiffs submit: In the *EA Construction*, the EA Court held that "light image data" was not limited to "pixel data values," but rather encompasses data structures other than pixels and data for a single pixel. There is no reason to deviate from the *EA Construction*. (Dkt. No. 93 at 20, 22–23.)

Defendants submit: The construction of "light image data" set forth in the *EA Construction* does not resolve the dispute between the parties here; namely, whether "light image data" must represent pixel data. As consistently and repeatedly described in the Asserted Patents, the light image data is pixels. Further, light image data must be in the form of pixels, or the claimed method cannot add the light image data to the light accumulation buffers for the pixels that are illuminated. In the '822 Patent IPR, Plaintiffs represented that the "light image data" are pixels, that this is an important aspect of the invention, and that this aspect is a distinction over the prior art. (Dkt. No. 90 at 34–37.)

In addition to the claims themselves, Defendants cite the following intrinsic evidence to support their position: '822 Patent figs.3–4, col.3 ll.40–52, col.4 ll.32–35, col.7 ll.15–17, col.7 ll.19–22, col.7 ll.30–32, col.7 ll.34–37, col.8 ll.8–10, col.8 ll.23–27, col.8 ll.45–47, col. 8 ll.57–60, col.8 ll.62–66, col.10 ll.63–66, col.11 ll.51–56; '822 Patent IPR Patent Owner Preliminary Response at 1–2, 5, 7–8, 11 (Defendants' Ex. H, Dkt. No. 91 at 181–91), Laub Decl. ¶¶ 56–57 (Defendants' Ex. L, Dkt. No. 91 at 210–24).

Plaintiffs respond: The Asserted Patents expressly provide that light image data may be formed as pixel values but that "other conventions and/or arrangements can also be used for storing and manipulating the data" (quoting '822 Patent col.7 ll.1–3). For example, and as explained in *Foley*, which is incorporated into the Asserted Patents by reference, it is known in the art that light image data may be stored in vector-system format or metafiles rather than as pixels. Further, dependent Claim 5 of the '822 Patent, for example, specifies when light-source data is associated with pixels, suggesting that light image data is not inherently pixels. Finally, neither Plaintiffs nor their expert witness characterized "light image data" as necessarily pixel data during the '822 Patent IPR. Specifically, the IPR statements that Defendants rely on are made in the context of

explaining the background of the technology or to note a distinction between the rendering method of the ’822 Patent and that of a prior art reference, rather than to distinguish the claims from prior art based on light image data necessarily being pixels. In fact, Plaintiffs acknowledged that the distinguished prior art reference in fact disclosed using pixel data. (Dkt. No. 96 at 25–32.)

Plaintiffs cite further intrinsic evidence to support their position: ’822 Patent col.7 ll.59–61, col.11 ll.51–61; ’822 Patent IPR Laub Decl. ¶¶ 56–57 (Defendants’ Ex. L, Dkt. No. 91 at 210–24), Patent Owner Preliminary Response at 5–7, 11–12 (Defendants’ Ex. H, Dkt. No. 91 at 181–91; Plaintiffs’ Ex. K, Dkt. No. 97-7), Hr’g Tr. at 50:9–11 (Plaintiffs’ Ex. L, Dkt. No. 97-8), *’822 Patent IPR Final* at 16–17 (Plaintiffs’ Ex. M, Dkt. No. 97-9); *Foley* at 9–12, 844, 849 (Plaintiffs’ Exs. F–H, Dkt. Nos. 97-2, 97-3, 97-4).

Defendants respond: In the EA Case, the EA Court did not have the benefit of the record of the Inter Partes Reviews when construing “light image data.” Here, the Court must construe the term in the full light of that record and hold Plaintiffs to statements made to secure patentability of the Asserted Patents. Further, the Court here should reconsider the *EA Construction* characterization of the disclosure at column 11, line 51–61 of the ’822 Patent. Specifically, rather than supporting that light image data may be polygons rather than pixels, it states the light image may be rendered for each polygon. This comports with light image data being pixels. (Dkt. No. 95 at 23–27.)

Defendants cite further extrinsic evidence to support their position: EA Case Ferraro Decl. ¶ 17 (Defendants’ Ex. E, Dkt. No. 91 at 107–18).

__Analysis__

The issue in dispute is whether "light image data" is necessarily in the form of pixels. Light image data is necessarily two-dimensional data that is distinct from depth data, but this does not mean that it is necessarily pixel values.

The Court generally agrees with the assessment of "light image data" set forth in the *EA Construction*. 2016 WL 5415429, at *10–11. Specifically, the Asserted Patents provide that "light image data" does not necessarily come in array or matrix form:

> With this in mind, FIG. 3 is a block diagram depicting exemplary arrangements of modeling data as used to render lighting and shadows, in accordance with certain embodiments of the present invention. For convenience, the various rendered data in FIG. 3 is illustrated as being logically stored in a plurality of 2D matrices or data bases 50 and 51A-G, each having an X axis and a Y axis. ***Preferably***, and in this example, the ***__X and Y axis correspond__ an exemplary output device 56 having a screen that __displays X by Y number of pixels__*** when provided corresponding red-green-blue (RGB) pixel data values. ***Those skilled in the art will recognize that other conventions and/or arrangements can also be used for storing and manipulating the data***.

'822 Patent col.6 l.58 – col.7 l.3 (emphasis added). In light of this disclosure, and with an understanding of "pixels" as "arrays of data corresponding to display device pixels," the EA Court held that "light image data" is not limited to "pixels." 2016 WL 5415429, at *11 ("'Light image data' is not necessarily in pixel (or array) form."), *15 ("As set forth in the above section on 'light image data' the Court does not understand that scene-view image data is necessarily in the form of pixels (or arrays of data corresponding to display-device pixels)"). Importantly, the EA Court did not hold that light image data may be other than 2D data. Indeed, the EA Court noted that the lighting data (which is defined by the light image data) represents a 2D view:

> That said, the Court understands that the "modeled point within said scene" refers to a point on a modeled 3D object within the simulated scene. But this does not mean that the "comparing" step necessarily is comparing 3D data. Rather, the claim language expresses that ***the comparison is between observer data and lighting data, both of which represent 2D views of the scene***.

Id. at *15 (emphasis added). The Court here agrees with the *EA Construction* to the extent that "light image data" is 2D data that is not necessarily limited to "arrays of data corresponding to display-device pixels." *Id*.

In the '822 Patent IPR, Plaintiffs represented the invention as operating at the "pixel level," but the Court does not understand this to equate "light image data" with arrays of data corresponding to display-device pixels. For instance, in the '822 Patent IPR, Plaintiffs stated that "***the '822 patent provides*** techniques that operate at a pixel level on fully rendered images in two-dimensional space, in contrast to scan-converted three-dimensional polygons." Preliminary Response at 1–2, IPR2016-00928, paper 6 (July 26, 2016) (emphasis added). Operating at the 2D level was presented to the PTAB as a point of novelty:

> To finally provide the rendered camera data that the '822 patent initially provides, Segal must perform scan-conversion of the 3D scene at every pass to incrementally render the camera data. As previously described, this scan conversion produces a series of screen points for every polygon in the scene. ***In contrast***, the '822 patent performs its lighting and shadowing on the X by Y array of pixels illustrated in Figure 3 of the '822 patent.

Id. at 11 (emphasis added). These statements are characterizations of the invention, not of an exemplary embodiment. That said, Plaintiffs also represented to the PTAB that "light image data" is "data representing the light emitted by each of the plurality of light sources." *Id*. at 17. Further, construing "light image data" as "pixel data" may suggest a correspondence between the display pixels and the "light image data." Indeed, Defendants suggested this at the hearing. Plaintiffs did not characterize "pixels" in this way in the '822 Patent IPR nor did the patentee characterize pixels this way in the Asserted Patents. In fact, the patents teach that "light image data" does not necessarily correspond to the display. *See, e.g.,* '822 Patent col.3 ll.24–35 (describing that the observer data, modified by the lighting data "if a modeled point within the scene is illuminated," is displayed, rather than the lighting data itself). This suggests that "light image data" is not

necessarily limited to pixels. Taken in its entirety and in context, the Preliminary Response in the '822 Patent IPR does not present a clear and unmistakable disclaimer of 2D data that are not pixels.

Accordingly, the Court construes "light image data" as follows:

- "light image data" means "for each of the plurality of light sources, 2D data representing the light emitted by the light source to illuminate the scene as viewed from the light source's perspective."

E. "storing at least a portion of said light image data associated with said point and said light source" and "at least a portion of"

Disputed Term	Plaintiffs' Proposed Construction	Defendants' Proposed Construction
"storing at least a portion of said light image data associated with said point and said light source" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	"at least a portion of" has its plain and ordinary meaning	storing all or a subset of said light image data associated with said point and said light source
"at least a portion of" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	plain and ordinary meaning	all or a subset of

Because the parties' arguments and proposed constructions with respect to these terms are related, the Court addresses the terms together.

<u>The Parties' Positions</u>

Plaintiffs submit: By limiting "at least a portion of" to "all or a subset of" Defendants' proposed construction threatens to improperly exclude a portion of the light image data that is a fractional portion of that data. (Dkt. No. 93 at 26–28.)

Defendants submit: The term "at least a portion of" needs to be construed to clarify that it does not encompass just any numerical derivative of the data. This comports with the reasoning expressed in the *EA Construction*, where the EA Court held that it "does not understand that the plain and ordinary meaning of 'at least of portion of' data encompasses any number that is a fractional component of one number within the set." This also comports with Plaintiffs' position in the EA Case, where Plaintiffs argued that the plain meaning of "at least of portion of" is "at least some but potentially all of." Finally, this comports with the disclosure of the Asserted Patents, which describes portions of data as subsets of the data rather than derivatives of the data. Ultimately, "storing data that are the result of performing mathematical operations on values identified as 'light image data' in the 'providing' step are not the same as storing 'at least a portion of' 'light image data.'" (Dkt. No. 90 at 41–45.)

In addition to the claims themselves, Defendants cite the following intrinsic and extrinsic evidence to support their position: Intrinsic evidence: '822 Patent fig.4, col.4 ll.34–35, col.7 ll.15–19, col.8 ll.45–60, col.8 ll.63–67, col.9 ll.1–12. Extrinsic evidence: EA Case Ferraro Decl. ¶ 21 (Defendants' Ex. E, Dkt. No. 91 at 107–18).

Plaintiffs respond: The plain meaning of "at least a portion of" data does not exclude fractional comparisons of the data, does not encompass a portion that does not correspond to the data, and does not exclude a portion that corresponds to the data but has also been altered or modified. (Dkt. No. 96 at 36–38.)

Defendants respond: As described in the Asserted Patents, "at least a portion of" data does not encompass "for example, dividing a number provided as light image data by another number and storing the result as being 'a portion of' any of the data." Specifically, "[p]erforming arbitrary

mathematical operations on the provided data and storing the result is not equivalent to storing 'at least a portion of' that data." (Dkt. No. 95 at 31–33.)

Defendants cite further **intrinsic evidence** to support their position: '822 Patent col.7 ll.46–48, col.8 l.39 – col.9 l.12.

Analysis

The issue in dispute distills to whether "at least a portion of" data necessarily refers to at least a subset of the data. As the Court understands Defendants' use of "subset," it does not. Specifically, "at least a portion of [data]" does not necessarily exclude transformed data, as Defendants contend.

The Court rejects Defendants' proposed construction that essentially requires the form of a portion of data to be the same as the form of the data. Indeed, this form-preserving limitation expressed in Defendants' argument threatens to exclude both exemplary and claimed embodiments. For instance, the claims recite "storing at least a portion of said light image data … in a light accumulation buffer." *See, e.g.*, '822 Patent col.12 ll.15–18. As explained in the Asserted Patents, the portion of light image data may be stored in the accumulation buffer by numerically adding it to values already in the accumulation buffer. *See, e.g., id*. at col.9 ll.42 ("ACCUM (SPx, SPy)+=LIGHT IMAGE (LPx, LPy)"). Indeed, this is a main aspect of the invention—to ***accumulate*** light on illuminated modeled points. Thus, the portion of data that is stored is mathematically transformed. Said differently, mathematically transforming light image data and storing the result is exactly what the patents disclose. This is encompassed by the claims.

Accordingly, the Court determines that "storing at least a portion of said light image data associated with said point and said light source" does not need to be construed apart from the construction of "at least a portion of." The Court finds that any interpretation of "at least a portion of" as requiring storing an untransformed subset of data would be inconsistent with the plain and

ordinary meaning of the term. Therefore, the Court rejects Defendants' "all or a subset of" limitation (as that proposed limitation is explained by Defendants), and determines that "at least a portion of" has its plain and ordinary meaning without the need for further construction.

F. "light accumulation buffer"

Disputed Term	Plaintiffs' Proposed Construction	Defendants' Proposed Construction
"light accumulation buffer" • '822 Patent Claim 1 • '488 Patent Claims 1, 27	memory for storing the light image data for cumulative light falling on a region in the observer image corresponding to a modeled point	memory for storing the light image data for cumulative light falling on each illuminated region in the observer image corresponding to a modeled point

<u>The Parties' Positions</u>

Plaintiffs submit: The Asserted Patents provide for storing only the portion of the scene that is changed, rather than storing "each illuminated region" as Defendants propose. In the EA Case, the EA Court reached this same conclusion when it held that the light data stored in the light accumulation buffer "may comprise data for only those pixels that change from frame to frame, and not all pixels must change." (Dkt. No. 93 at 28–31.)

In addition to the claims themselves, Plaintiffs cite the following **intrinsic evidence** to support their position: '822 Patent col.7 ll.47–49, col.8 ll.57–67, col.11 ll.15–27, col.11 ll.58–59.

Defendants submit: The *EA Construction* did not address the dispute between the parties here; namely, whether the light accumulation buffer necessarily stores data for each illuminated region. As described in the Asserted Patents, the light accumulation buffer accumulates light for each lit pixel in the scene. It thus stores light image data for each illuminated region. This is how Plaintiffs' expert in the '822 Patent IPR characterized the light accumulation buffer to the PTAB and this is

how Plaintiffs presented the light accumulation buffer to the EA Court in the EA Case. (Dkt. No. 90 at 38–41.)

In addition to the claims themselves, Defendants cite the following intrinsic evidence to support their position: ’822 Patent figs.3–4, col.7 ll.4–6, col.7 ll.15–53, col.7 ll.46–52, col.8 l.39 – col. 9 l.5, col.9 ll.8–12; ’822 Patent IPR Laub Decl. ¶¶ 62–63 (Defendants’ Ex. L, Dkt. No. 91 at 210–24).

Plaintiffs respond: Defendants’ proposed construction would require processing of every region in a scene for every frame in order to store each region, which contradicts the Asserted Patents’ teachings that only regions that change from frame to frame need to be processed and the lighting results stored. (Dkt. No. 96 at 32–36.)

Plaintiffs cite further intrinsic evidence to support their position: ’822 Patent col.3 ll.15–19, col.11 ll.18–30, col.8 ll.56–60.

Defendants respond: As explained in the patents, the purpose of the light accumulation buffer is to accumulate “light from all the light sources that illuminate each pixel in the observer image.” For pixels that do not change from frame to frame, the data in the buffer does not change and does not need to be recomputed, but it is still stored. (Dkt. No. 95 at 28–31.)

Defendants cite further intrinsic evidence to support their position: ’822 Patent col.9 ll.3–12; *’822 Patent IPR Institution* at 12–13 (Defendants’ Ex. Q, Dkt. No. 95-1 at 9–16).

<u>Analysis</u>

The issue in dispute is whether the light accumulation buffer necessarily stores data for each illuminated region in a scene. While the claims plainly require that the accumulation buffer stores certain light data “for each of [a] plurality of light sources,” they require storage of data for only

"an" illuminated modeled point, not all points. That is, the claims do not require (though they encompass) accumulating light for every modeled point in the scene.

The claims require processing of each of a plurality of light sources, but do not expressly require processing of each modeled point in a scene. For example, Claim 1 of the '822 Patent, produced and annotated here, recites that "for each" light source, "determine if ***a*** modeled point … is illuminated … and storing at least a portion of said light image data … in a light accumulation buffer." The claim does not express that light is stored in the accumulation buffer for each illuminated point. The lack of an express for-each-illuminated-point limitation is meaningful, especially considering the claim expressly requires that light is stored for each light source associated with an illuminated point. Further, the Asserted Patents specifically teach that the accumulation buffer may not store lighting data for all portions of a scene. For example, the patents provide that only a partial view needs to be processed to provide lighting and shadow rendering:

> '822 Patent
>
> **1**. A shadow rendering method for use in a computer system, the method comprising the steps of:
>
> providing observer data of a simulated multi-dimensional scene;
>
> providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;
>
> ***for each*** ***of said plurality of light sources***, comparing at least a portion of said observer data with at least a portion of said lighting data to ***determine if a modeled point within said scene is illuminated*** by said light source and ***storing at least a portion of said light image data associated with said point*** and said light source in a light accumulation buffer; and then
>
> combining at least a portion of said light accumulation buffer with said observer data; and
>
> displaying resulting image data to a computer screen.

RENDER EACH VIEW (***PARTIAL*** IF THE LIGHT IS STATIONARY)
CLEAR ACCUM BUFFER
FOR EACH LIGHT SOURCE …
    FOR EACH PIXEL IN CAMERA IMAGE SPxSPy…
        TRANSFORM EACH SP TO A LP {LIGHT PIXEL} USING EITHER:
            TRANSFORM LOOK-UP TABLE,

> OR
> MATRIX TRANSFORMATION CALCULATION
> IF LP2 <LIGHT DEPTH (LPx, LPy) THEN
> ACCUM (SPx, SPy)+=LIGHT IMAGE (LPx, LPy)
> FOR EACH PIXEL IN CAMERA IMAGE …
> CAMERA IMAGE (SPx, SPy)*=ACCUM (SPx, SPy)

’822 Patent col.9 ll.31–44 (emphasis added). That only partial views are rendered but the accumulation buffer is cleared for each rendering pass (“CLEAR ACCUM BUFFER”) indicates that the accumulation buffer does not necessarily store accumulated light for all points in the scene. This is further explained with reference to an exemplary application of the process:

> With regard to man 208 as depicted in depth image 220, the depth image 220 has been further processed in this example to include data relating to the depth of man 208. This can be accomplished, for example, by comparing previous frames and completing new transform calculations for pixels that have changed and that are in the depth image for the light source. Thus, for example, from the previous frame, man 208 may have moved slightly (e.g., in response to inputs from the user). A portion of the pixels are identified as having changed from the previous frame. The portion of the pixels that changed are then transformed and processed to generate new modified light depth data 228. In this manner, ***only those portions of the scene that change need to be reprocessed***.

Id. at col.11 ll.14–27 (emphasis added). Thus, the light accumulation buffer does not necessarily store data for every illuminated point, or region, in the scene.

Finally, the parties each propose “corresponding to ***a*** modeled point” in their constructions, but “corresponding to ***the*** modeled point” better reflects the surrounding claim language, which indicates that the information that is stored in the accumulation buffer is light image data associated with the modeled point determined to be illuminated by the light source. *See, e.g.*, ’822 Patent col.12 ll.11–18 (Claim 1, reciting “determine if a modeled point within said scene is illuminated by said light source and ***storing*** at least a portion of said ***light image data associated with <u>said</u> point***” (emphasis added)).

Accordingly, the Court construes “light accumulation buffer” as follows:

- "light accumulation buffer" means "memory for storing the light image data for cumulative light falling on a region in the observer image corresponding to the modeled point."

V. CONCLUSION

The Court adopts the constructions set forth above, as summarized in the following table. The parties are **ORDERED** that they may not refer, directly or indirectly, to each other's claim-construction positions in the presence of the jury. Likewise, the parties are **ORDERED** to refrain from mentioning any portion of this opinion, other than the actual definitions adopted by the Court, in the presence of the jury. Any reference to claim-construction proceedings is limited to informing the jury of the definitions adopted by the Court.

Group	Term	Construction
A	"A shadow rendering method for use in a computer system" • '822 Patent Claim 1	the preamble is not limiting
	"A shadow rendering method" • '488 Patent Claim 1	the preamble is not limiting
B	"determine if a modeled point within said scene is illuminated by said light source" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	determine if a point on a modeled object within said scene is illuminated by said light source
C	"providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	plain and ordinary meaning, subject to construction of "light image data"

Group	Term	Construction
D	"light image data" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	for each of the plurality of light sources, 2D data representing the light emitted by the light source to illuminate the scene as viewed from the light source's perspective
E	"storing at least a portion of said light image data associated with said point and said light source" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	plain and ordinary meaning
	"at least a portion of" • '822 Patent Claim 1 • '488 Patent Claims 1, 11, 27	plain and ordinary meaning
F	"light accumulation buffer" • '822 Patent Claim 1 • '488 Patent Claims 1, 27	memory for storing the light image data for cumulative light falling on a region in the observer image corresponding to the modeled point
AGREED	"providing" • '822 Patent Claim 1 • '488 Patent Claims 1, 27	making available
	"observer data of a simulated multi-dimensional scene" • '822 Patent Claim 1 • '488 Patent Claims 1, 27	data representing at least the color of objects in a simulated multi-dimensional scene as viewed from an observer's perspective
	"observer data associated with a simulated multi-dimensional scene" • '488 Patent Claim 11	
	"a modeled point within said scene" • '822 Patent Claims 1, 6 • '488 Patent Claims 1, 11, 27	a point on a modeled object within said scene

Group	Term	Construction
	order of the comparing, storing, and combining steps • ’822 Patent Claim 1 • ’488 Patent Claims 1, 11, 27	the comparing and storing steps are completed before beginning the combining step
	“displaying resulting image data to a computer screen” • ’822 Patent Claim 1	displaying the image data resulting from combining at least a portion of the light accumulation buffer with the observer data on a computer screen
	“outputting resulting image data” • ’488 Patent Claims 1, 27	outputting for presentation to a user the image data resulting from combining at least a portion of the light accumulation buffer with the observer data
	“combining at least a portion of said light accumulation buffer with said observer data” • ’822 Patent Claim 1 • ’488 Patent Claims 1, 11, 27	combining at least a portion of the data in the light accumulation buffer with said observer data • subject to the above constructions of “at least a portion of,” “light accumulation buffer,” and “observer data …”
	“A computer-readable medium carrying at least one set of computer instructions configured to cause at least one processor to operatively render simulated shadows in a multidimensional simulated scene” • ’488 Patent Claim 27	the preamble is limiting

SO ORDERED.

September 6, 2019.

Barbara M G Lynn

BARBARA M. G. LYNN
CHIEF JUDGE

US006362822B1

(12) **United States Patent**
Randel

(10) **Patent No.: US 6,362,822 B1**
(45) **Date of Patent: Mar. 26, 2002**

(54) **LIGHTING AND SHADOWING METHODS AND ARRANGEMENTS FOR USE IN COMPUTER GRAPHIC SIMULATIONS**

(75) Inventor: **Mark R. Randel**, Flower Mound, TX (US)

(73) Assignee: **Terminal Reality, Inc.**, Lewisville, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/268,078**

(22) Filed: **Mar. 12, 1999**

(51) **Int. Cl.**[7] **G06T 17/00**

(52) **U.S. Cl.** **345/426**

(58) **Field of Search** 345/418, 419, 345/425, 426, 427, 114, 117, 118

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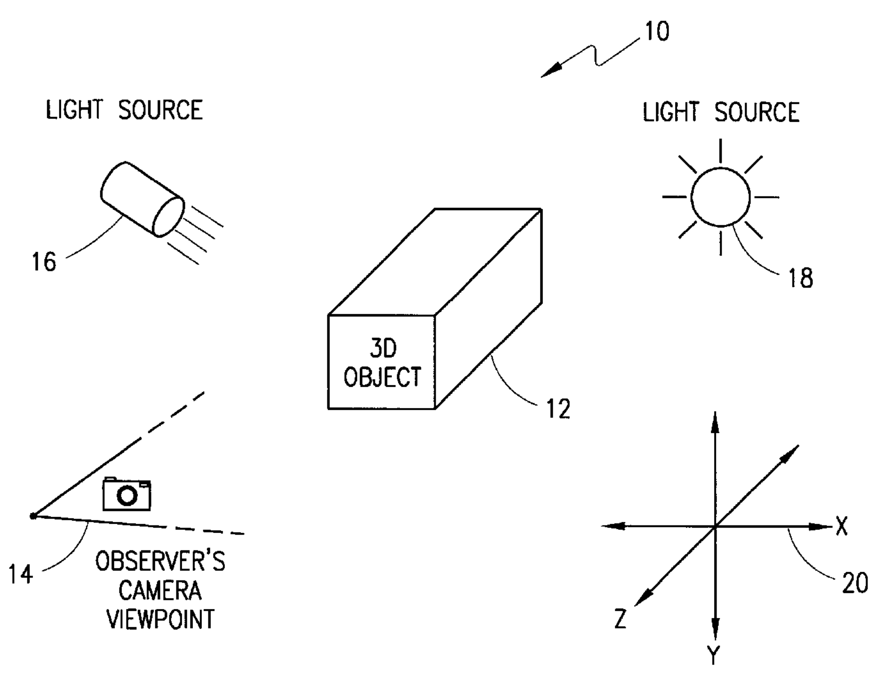
* cited by examiner

Primary Examiner—Cliff N. Vo
(74) *Attorney, Agent, or Firm*—Jenkens & Gilchrist, P.C.

(57) **ABSTRACT**

The effects of lighting and resulting shadows within a computer simulated three-dimensional scene are modeled by rendering a light depth image and a light color image for each of the light sources. The light depth images are compared to a camera depth image to determine if a point within the scene is lighted by the various light sources. An accumulated light image is produced by combining those portions of the light color images determined to be lighting the scene. The resulting accumulated light image is then combined with a camera color image to produce a lighted camera image that can be further processed and eventually displayed on a computer display screen. The light color image can be static or dynamic. Transformations between different perspective and/or coordinate systems can be pre-calculated for fixed cameras or light sources. The various images and manipulations can include individual pixel data values, multiple-pixel values, polygon values, texture maps, and the like.

48 Claims, 6 Drawing Sheets



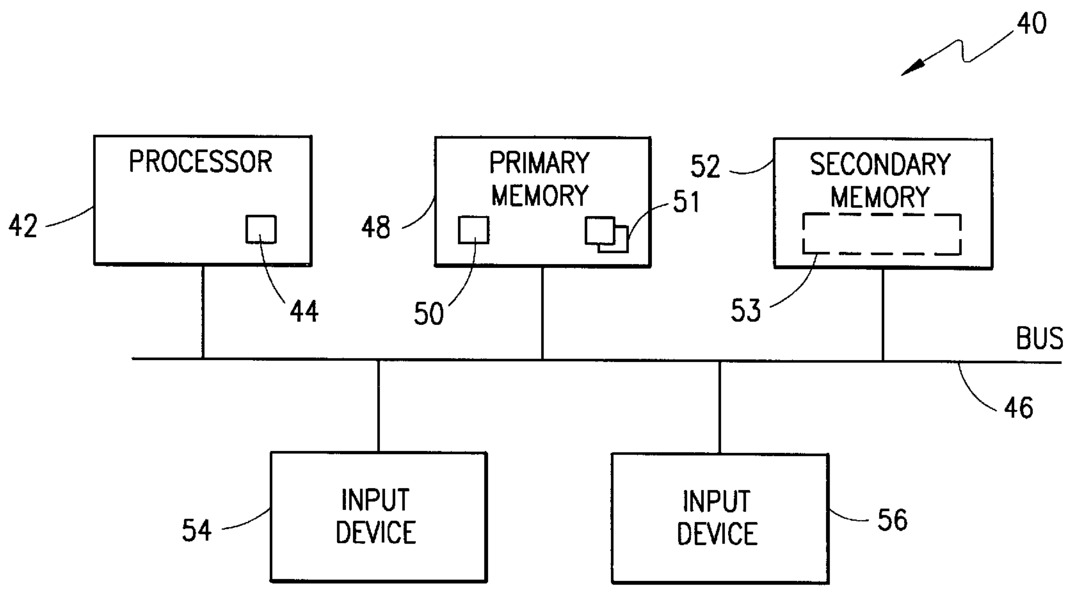

40
PROCESSOR
42
44
PRIMARY MEMORY
48
50
51
52
SECONDARY MEMORY
53
BUS
46
INPUT DEVICE
54
INPUT DEVICE
56

FIG. 1

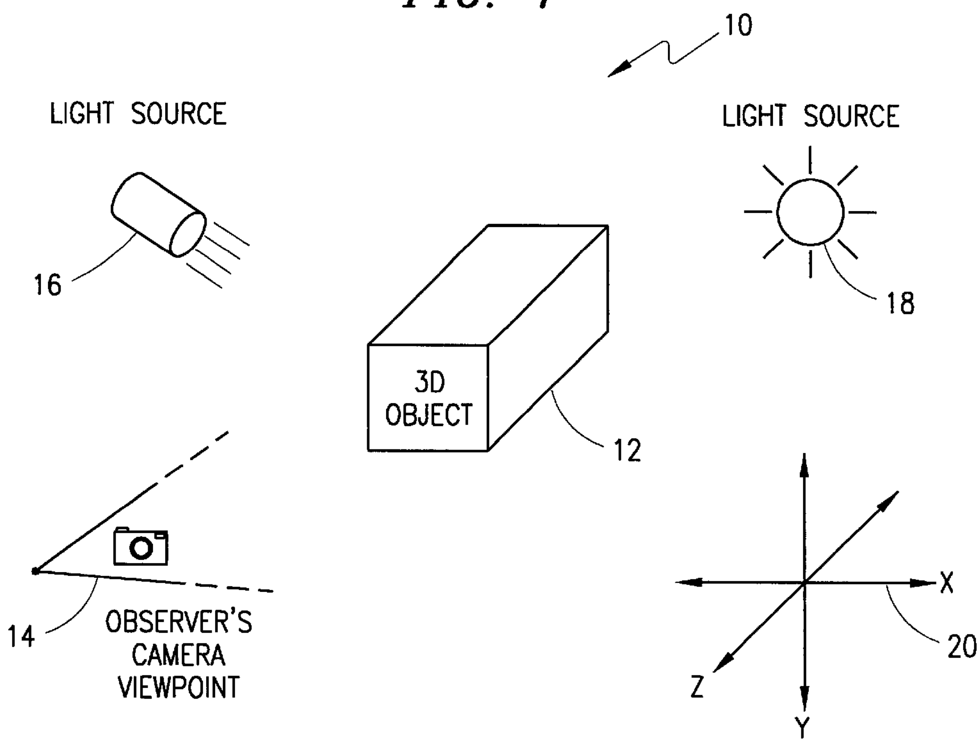

10
LIGHT SOURCE
16
LIGHT SOURCE
18
3D OBJECT
12
14
OBSERVER'S CAMERA VIEWPOINT
X
Y
Z
20

FIG. 2

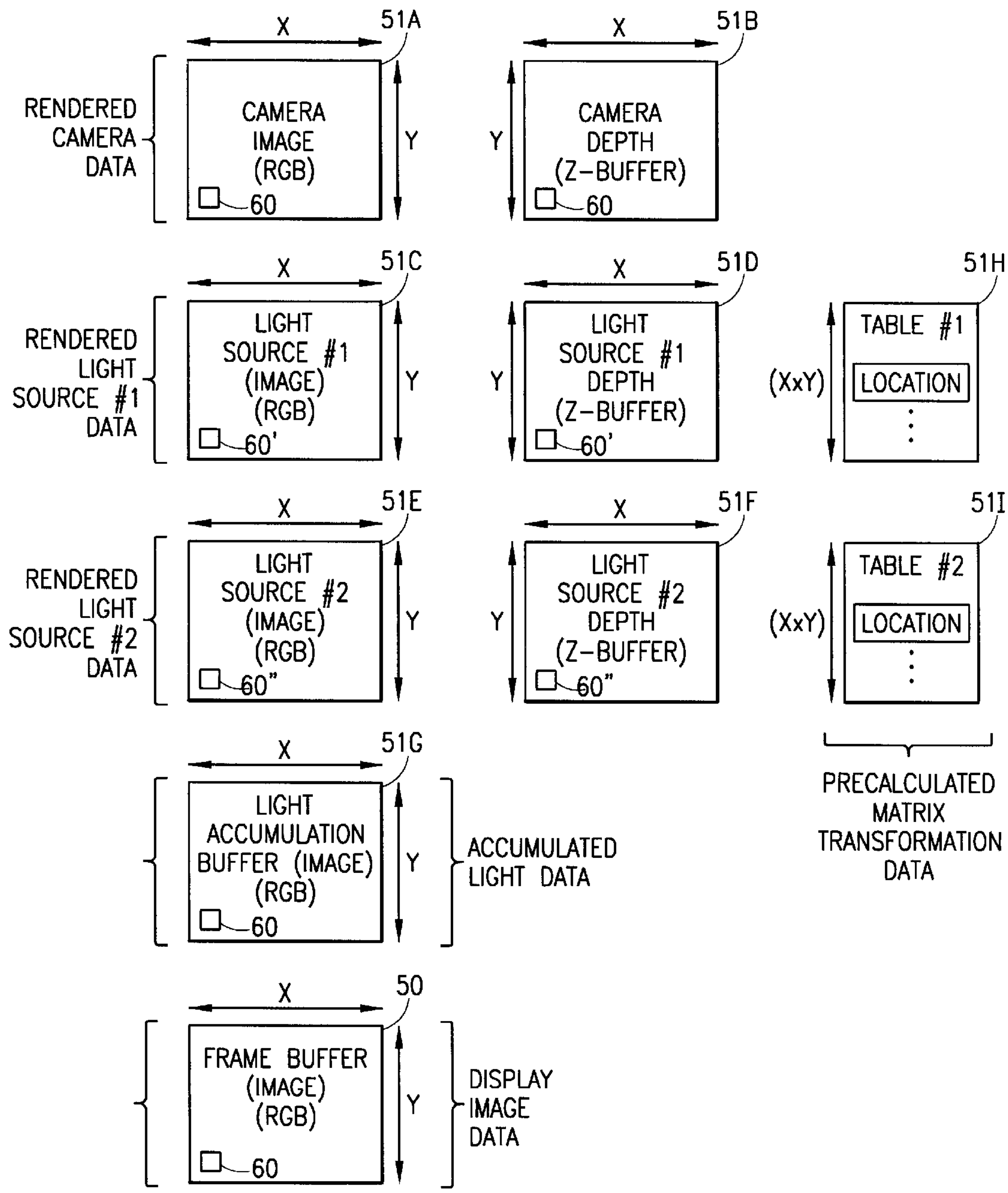

51A
X
RENDERED CAMERA DATA
CAMERA IMAGE (RGB)
60
Y
51B
X
Y
CAMERA DEPTH (Z-BUFFER)
60
51C
RENDERED LIGHT SOURCE #1 DATA
LIGHT SOURCE #1 (IMAGE) (RGB)
60'
51D
LIGHT SOURCE #1 DEPTH (Z-BUFFER)
60'
51H
(XxY)
TABLE #1
LOCATION
51E
RENDERED LIGHT SOURCE #2 DATA
LIGHT SOURCE #2 (IMAGE) (RGB)
60"
51F
LIGHT SOURCE #2 DEPTH (Z-BUFFER)
60"
51I
TABLE #2
LOCATION
PRECALCULATED MATRIX TRANSFORMATION DATA
51G
LIGHT ACCUMULATION BUFFER (IMAGE) (RGB)
60
ACCUMULATED LIGHT DATA
50
FRAME BUFFER (IMAGE) (RGB)
60
DISPLAY IMAGE DATA

FIG. 3

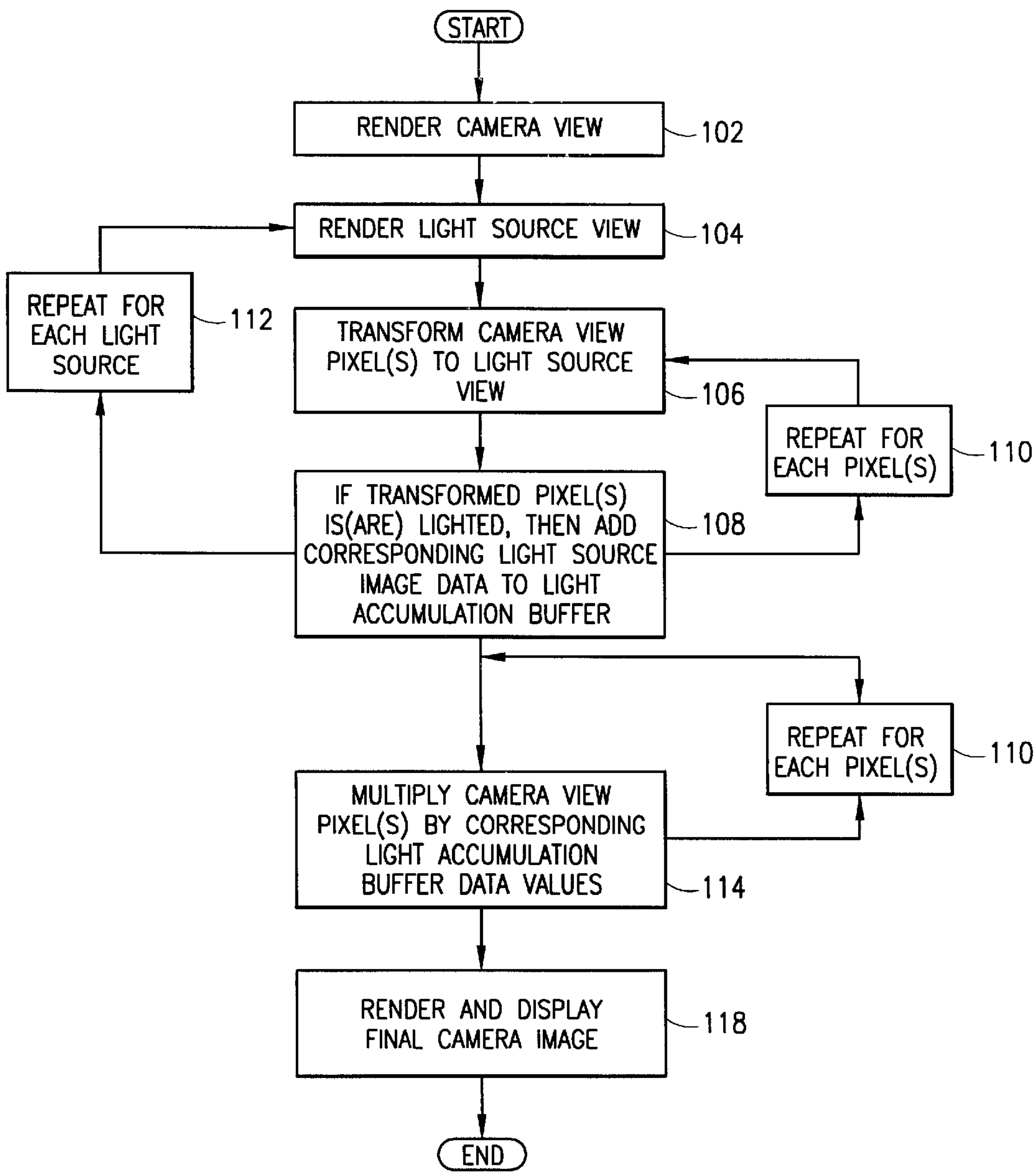

START
RENDER CAMERA VIEW
102
RENDER LIGHT SOURCE VIEW
104
REPEAT FOR EACH LIGHT SOURCE
112
TRANSFORM CAMERA VIEW PIXEL(S) TO LIGHT SOURCE VIEW
106
REPEAT FOR EACH PIXEL(S)
110
IF TRANSFORMED PIXEL(S) IS(ARE) LIGHTED, THEN ADD CORRESPONDING LIGHT SOURCE IMAGE DATA TO LIGHT ACCUMULATION BUFFER
108
REPEAT FOR EACH PIXEL(S)
110
MULTIPLY CAMERA VIEW PIXEL(S) BY CORRESPONDING LIGHT ACCUMULATION BUFFER DATA VALUES
114
RENDER AND DISPLAY FINAL CAMERA IMAGE
118
END

FIG. 4

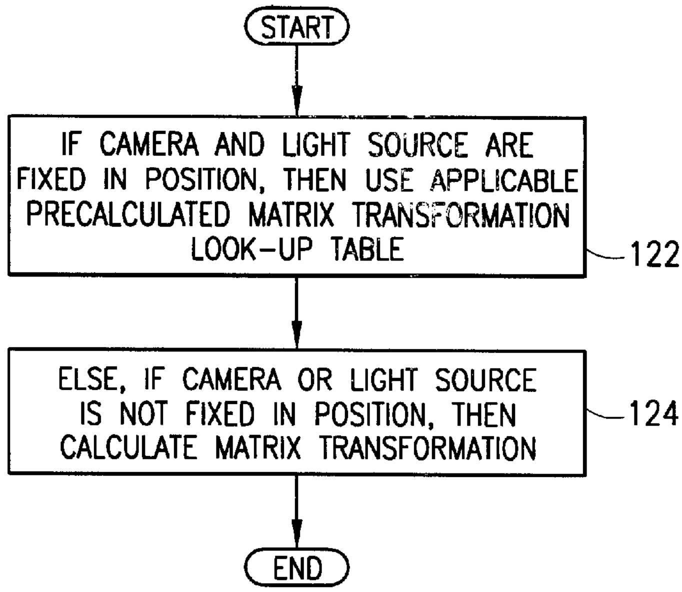

START
IF CAMERA AND LIGHT SOURCE ARE FIXED IN POSITION, THEN USE APPLICABLE PRECALCULATED MATRIX TRANSFORMATION LOOK-UP TABLE
122
ELSE, IF CAMERA OR LIGHT SOURCE IS NOT FIXED IN POSITION, THEN CALCULATE MATRIX TRANSFORMATION
124
END

FIG. 5

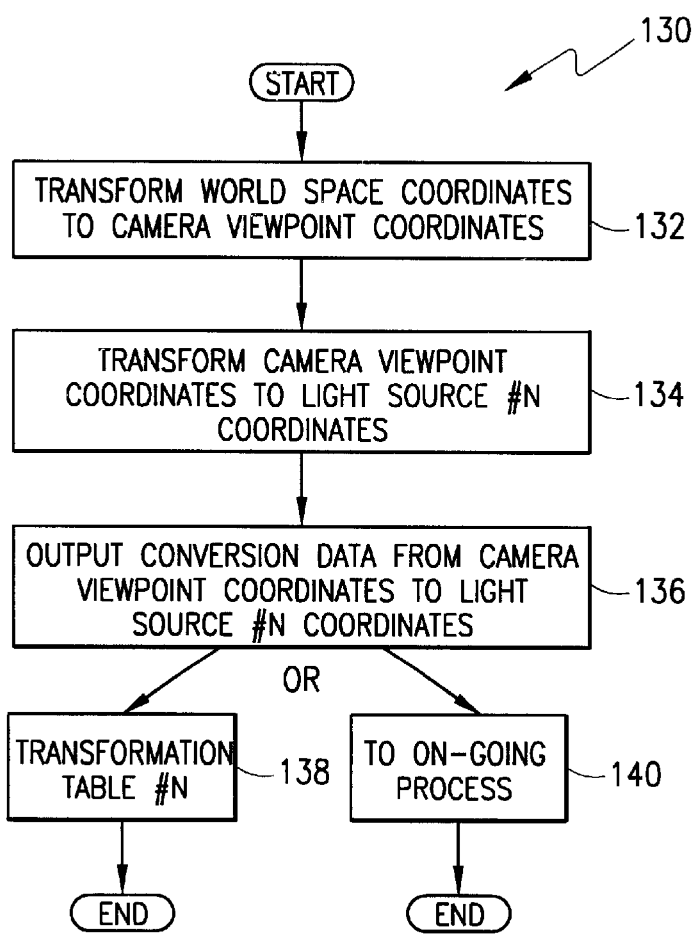

130
START
TRANSFORM WORLD SPACE COORDINATES TO CAMERA VIEWPOINT COORDINATES
132
TRANSFORM CAMERA VIEWPOINT COORDINATES TO LIGHT SOURCE #N COORDINATES
134
OUTPUT CONVERSION DATA FROM CAMERA VIEWPOINT COORDINATES TO LIGHT SOURCE #N COORDINATES
136
OR
TRANSFORMATION TABLE #N
138
TO ON-GOING PROCESS
140
END
END

FIG. 6

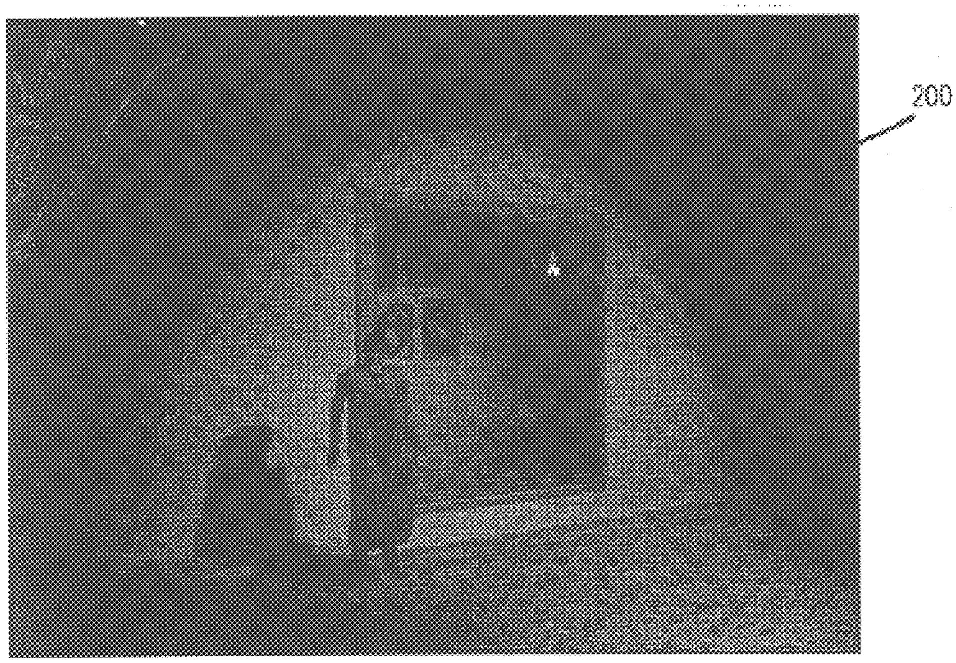

200

FIG. 7A

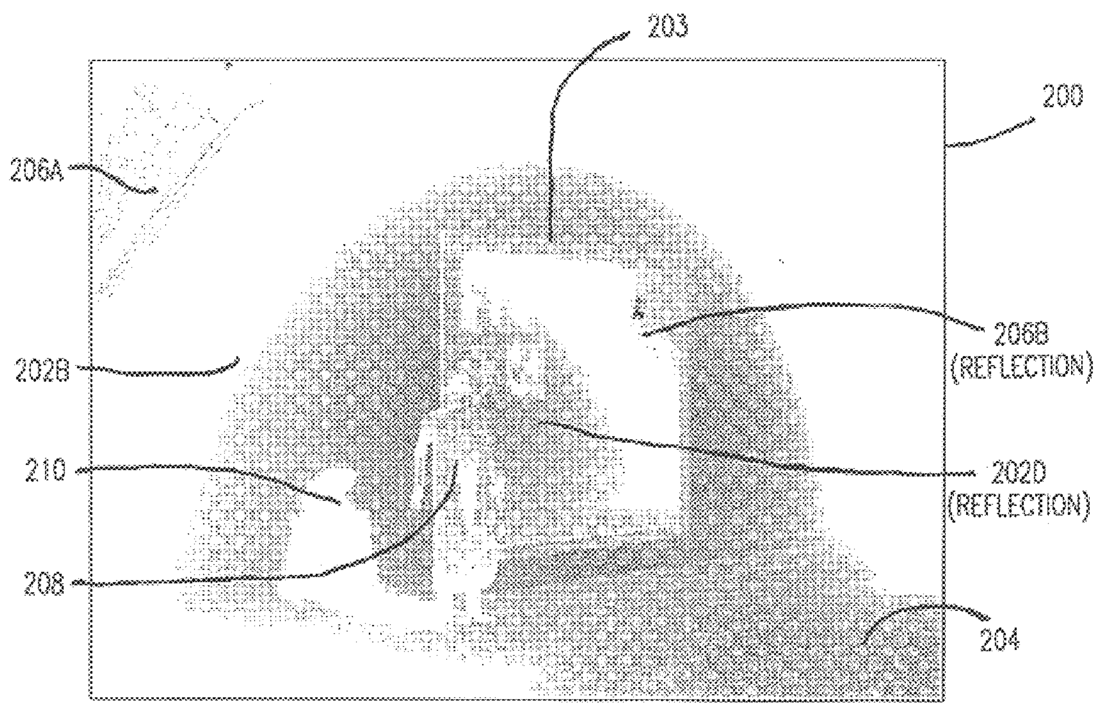

203
200
206A
206B (REFLECTION)
202B
210
202D (REFLECTION)
208
204

FIG. 7B

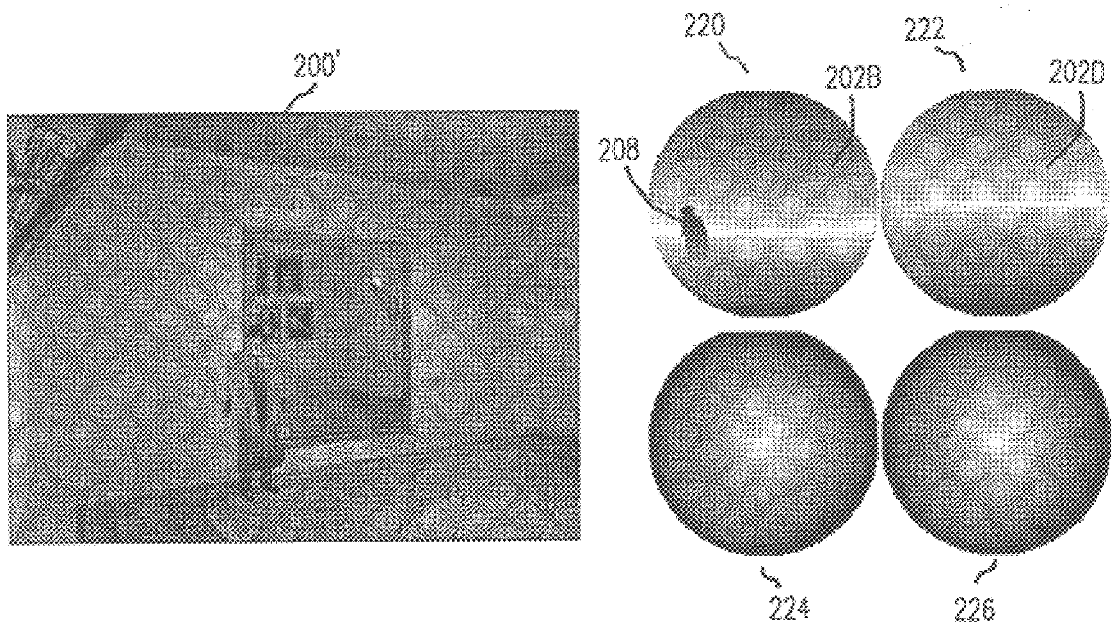

200'
220
222
202B
202D
208
224
226

FIG. 7C

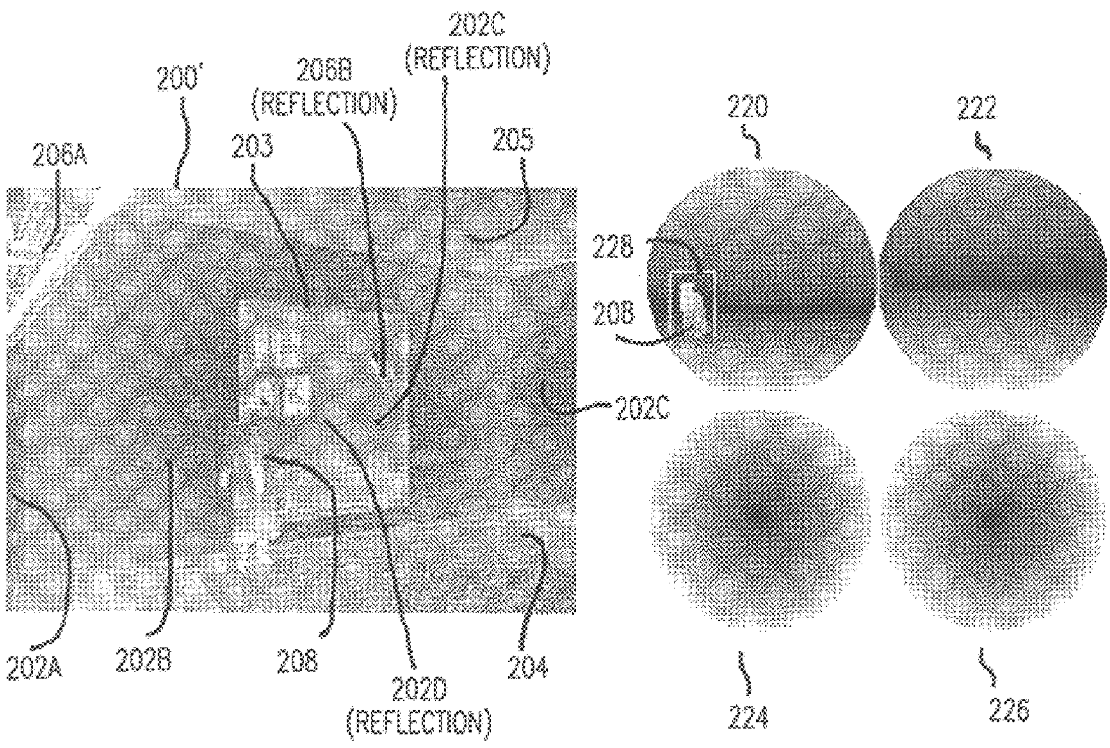

202C
(REFLECTION)
200'
206B
(REFLECTION)
206A
203
205
220
222
228
208
202C
202A
202B
208
202D
(REFLECTION)
204
224
226

FIG. 7D

LIGHTING AND SHADOWING METHODS AND ARRANGEMENTS FOR USE IN COMPUTER GRAPHIC SIMULATIONS

TECHNICAL FIELD OF THE INVENTION

The present invention relates to computer graphics and, more particularly, to improved methods and arrangements for use in rendering lighting and shadows in computer graphic simulations, such as, for example, interactive computer graphics simulations of multi-dimensional objects.

BACKGROUND

Computer generated graphics are becoming more popular in everyday computing especially given recent advances in affordable computer hardware and software. This trend is expected to continue in the foreseeable future. By way of example, interactive computer generated graphical images are becoming increasingly detailed and more realistic due to increased processing capabilities in personal computers (PCs). No where is this more evident than in the computer gaming arena, wherein virtual three-dimensional (3D) worlds are created in software and interactively explored by the computer's user.

As with the real World, these virtual 3D worlds consist of a plurality of 3D objects. These 3D objects are typically modeled by one or more polygons. In the computer, depending upon the orientation of the scene being viewed, some of these polygons correspond to individual pixels that are displayed on the computer's display screen. Within the computer, these pixels are represented by data that can be manipulated and stored in at least one data base. For example, once the arrangement of these 3D objects with respect to one another has been determined for a particular viewpoint, the rendered scene of the 3D world is projected onto a two-dimensional (2D) frame that can be displayed to the user. The frame is typically a data base that contains pixel color information with regard to the display screen.

A sense of motion within this virtual 3D world is provided by incrementally altering the arrangement of these 3D objects and quickly re-displaying the transformed frame. Typically, a frame rate of at least about twenty-five (25) frames-per-second (fps) is desired to convey a sense of motion.

Rendering such interactive 3D worlds, however, typically requires that millions of calculations be conducted between frames (i.e., in "real time"). Since there is a limit to the amount of processing that a computer can provide between frames, simplifications or other compromises often need to be made in modeling a 3D world. Additionally, advanced algorithms are implemented in either hardware and/or software to further streamline the processing of the resulting 3D scene and 2D images. Regardless of how the rendering computations are completed, the goal remains the same, namely, to provide a realistic, interactive virtual 3D world to the user.

One of the unfortunate compromises made in the past, has been in the area of lighting and, more particularly, in the area of rendering shadows cast by lighted 3D objects. Many shadow rendering processes have been considered to be too compute intensive for most lower-end computer applications, and as such shadow rendering is often ignored or otherwise greatly simplified. Several advanced and simplified shadow rendering algorithms and other graphical algorithms and techniques are described by James D. Foley, et al. in *Computer Graphics: Principles and Practice*, second edition, 1997 (ISBN 0-201-84840-6), published by

Addison-Wesley Publishing Company, Inc. This text is expressly incorporated herein, by reference, in its entirety and for all purposes.

By way of a particular example, Foley et al. describe a promising two-pass object-precision shadow algorithm in Section 16.4.2 of the text. This two-pass shadow algorithm, developed by Atherton, Weiler and Greenberg, essentially determines which portions on a 3D object's surfaces are visible from the perspective of a light source (i.e., from the light source's view point). This requires converting the data for the 3D object, as represented in a data base, from a modeled world coordinate to a light source coordinate and then determining which portions of the various polygons are visible surfaces with respect to the light source, for example, using a hidden-surface removal algorithm. Since these visible portions are illuminated (i.e., lit) by the light source, the remaining portions (i.e., the hidden-surfaces) are darkened as being shaded from the light. The resulting data is then transformed back to modeling world coordinates and merged with the original object data base. This creates a viewpoint-independent merged data base that can be used to determine the shadows on the various 3D objects from any other viewpoint. This is the first step of the two-step shadow algorithm.

In the second step of the two-pass shadow algorithm, the data in the merged data base is then converted from the modeled world space to a corresponding screen (or camera) viewpoint. Then, a hidden-surface algorithm is used to determine which portions of the various polygons are visible surfaces with respect to the camera. These visible portions are identified as being visible to the camera and as being either not-darkened (i.e., lit) or darkened (i.e., in a shadow). A polygon scan-conversion algorithm is then used to render the resulting 2D image.

One of the drawbacks to this type of shadow algorithm is that unrealistic shadowing can occur in scenes having multiple light sources. Foley et al. for example, one page 747 of their text, teach that multiple light sources are handled by re-processing the merged data base for each new light source. Thus, for example, assume that a portion of a polygon which is visible from the camera viewpoint has been darkened because it is shaded from a first light source. This is information is recorded in the merged data base. Then, this merged data base is used as the starting point for a similar process for the second light source's viewpoint determination. As part of this second light source's viewpoint determination, additional darkening can occur to portions of the scene that are also shaded from the second light source. As a result, there is a potential for a portion of the scene to be darkened twice. In scenes having multiple light sources, including ambient light, this additive darkening of portions, and in particular, pixels, tends to reduce the realism of the shadowing effects and can lead to awkward shadowing cross-talk, wherein a shadow is made overly dark and has unrealistic transitions. This is especially true for applications using a "stencil buffer" technique for shadowing.

Additionally, when there are several light sources, for examples four or more, the transformation process associated with converting between the camera, world, and light viewpoints in support of this type of two pass algorithm can prove to be too burdensome, thereby inhibiting or otherwise diminishing the effectiveness of the resulting interactive real-time graphics.

Consequently, there is need for improved shadow rendering methods and arrangements. Preferably, the improved shadow rendering methods and arrangements support real

time interactive graphics on conventional PCs and the like, and allow for multiple light sources to be modeled in a more efficient and realistic manner.

SUMMARY OF THE INVENTION

In accordance with certain aspects of the present invention, improved lighting and shadow rendering methods and arrangements are provided. These improved lighting and shadow rendering methods and arrangements can be implemented to support real time interactive graphics on conventional computers such as personal computers (PCs), computer gaming devices and the like. These improved methods and arrangements allow for multiple light sources to be modeled in a more efficient and realistic manner without becoming overly burdensome, or otherwise inhibiting or diminishing the effectiveness of the resulting interactive real time graphics.

For example, the above stated needs and others are met by a shadow rendering method for use in a computer system, in accordance with certain embodiments of the present invention. The method includes the steps of providing observer data of a simulated multi-dimensional scene and providing lighting data associated with a plurality of simulated light sources arranged to illuminate the scene. This lighting data includes light image data, for example. For each of the light sources, the method then includes the steps of comparing at least a portion of the observer data with at least a portion of the lighting data to determine if a modeled point within the scene is illuminated by the light source, and storing at least a portion of the light image data associated with the point and the light source in a light accumulation buffer. Once this is completed, the method includes the steps of combining at least a portion of the light accumulation buffer with the observer data, and displaying the resulting image data to a computer screen.

In accordance with certain further embodiments of the present invention, the observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within the scene as rendered from an observer's perspective. Thus, for example, the modeled polygons can be associated with a single pixel on the computer screen or a group of pixels, wherein the observed color data includes an observed red-green-blue value for the pixel(s) and the observed depth data includes an observed z-buffer value for the pixel(s). Similar data is provided for the lighting data, wherein, in certain embodiments, the lighting data includes source color data associated with at least one of the light sources and source depth data associated with the plurality of modeled polygons within the scene as rendered from a plurality of different light source's perspectives.

In accordance with still further embodiments of the above method, at least a portion of the observed depth data is compared with at least a portion of the source depth data to determine if the modeled point is illuminated by the light source. This can include, for example, converting at least a portion of the observed depth data from the observer's perspective to at least one of the plurality of different light source's perspectives, before comparing the observed depth data with the source depth data. For fixed light sources and/or observer a precalculated matrix transformation look-up table can be used.

In accordance with other embodiments of the present invention, the above method can also be used to simulate dynamically changing light sources, interrupted light beams, reflected light beams, and/or projected light images, such as, for example, motion picture, video, animation, and computer graphics images. This can be accomplished, for example, by having at least a portion of the source color data being selectively controlled source color data, which can be changed over a period of time.

An arrangement that is configured to render shadows in a simulated multi-dimensional scene is also provided to meet the above stated needs and others, in accordance with certain further embodiments of the present invention. The arrangement includes a display screen configured to display image data, memory for storing data, such as, observer data, lighting data, light accumulation data, and frame data. At least one processor is coupled to the memory and the display screen and operatively configured to compare, for each of the plurality of light sources, observer data with lighting data to determine if a modeled point within the scene is illuminated by the light source and, if so, to store light image data in a light accumulation buffer, which can then be combined with observer data, and stored in the frame buffer for display via the display screen.

In accordance with still further embodiments of the present invention a method for simulating light falling on a modeled object in a computer generated multi-dimensional graphics simulation is provided. This method includes rendering a camera view of an object to produce a camera depth array and a corresponding camera image array, rendering at least one light view of the object to produce a light depth array and a corresponding light image array, and transforming camera depth data to the light view to produce a transformed camera array. The method further includes, for each data value therein, comparing the light depth array to the transformed camera array to determine if the data value in the light depth array is closer to the simulated light, and if so, adding a corresponding data value from the light image array to a light accumulation array, and then for each data value therein, multiplying the camera image array by a corresponding data value from the light accumulation array to produce a lighted camera image array.

The improved methods and arrangements of the present invention can be implemented in hardware and/or software. Thus, in accordance with certain embodiments of the present invention, a computer-readable medium is provided. A computer readable medium, by way of example, can include any tangible apparatus suitable for conveying or otherwise carrying at least one set of computer instructions. This can include a removable media associated with a computer system or a data communications link or network over which computer implemented instructions and/or data are carried, for example.

Thus, in accordance with certain embodiments of the present invention, such computer instructions are configured to cause a computer to operatively simulate light falling on a modeled object in a computer generated multi-dimensional graphics simulation by performing the following operations: 1) rendering an observer view; 2) rendering a source view; 3) transforming observed depth values to the source view; 4) modifying at least one image accumulation value with one of the observed image values if the corresponding transformed observer value is equal to a comparable one of the source depth values; 5) multiplying the one of the observed image values by the at least one image accumulation value to produce at least one pixel value; and 6) displaying the pixel value on a computer screen. In certain embodiments, following operation 4), operations 2) through 4) are repeated for each additional source.

In accordance with yet other embodiments of the present invention, there is provided a computer-readable medium

carrying at least one set of computer instructions configured to cause at least one processor within a computer system to operatively render simulated shadows in a multi-dimensional simulated scene by performing the steps of providing observer data, providing lighting data, comparing observer data with lighting data to determine if a modeled point within the scene is illuminated by the light source, storing at least a portion of the light image data associated with the point and the light source in a light accumulation buffer, combining at least a portion of the light accumulation buffer with the observer data, and displaying resulting image data to a computer screen.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and arrangements of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

FIG. **1** is a block diagram depicting a computer system that is configured to generate and display interactive 3D graphics, in accordance with certain embodiments of the present invention;

FIG. **2** is a block diagram depicting an exemplary 3D graphics scene that can be rendered by a computer system as in FIG. **1**, in accordance with certain embodiments of the present invention;

FIG. **3** is a block diagram depicting exemplary arrangements of modeling data as used to render shadows, for example, using the computer system in FIG. **1**, in accordance with certain embodiments of the present invention;

FIG. **4** is an exemplary flow-chart depicting an improved shadow rendering process, for use in a computer system, for example, as in FIG. **1**, in accordance with certain embodiments of the present invention;

FIG. **5** is an exemplary flow-chart depicting further enhancements to the improved shadow rendering process in FIG. **4**, in accordance with certain further embodiments of the present invention;

FIG. **6** is an exemplary flow-chart depicting further enhancements to the process in FIG. **5**, in accordance with still further embodiments of the present invention; and

FIGS. **7**A–D are photocopies of exemplary computer screen print-outs depicting an exemplary 3D scene and related rendered depth and image data from an interactive real time graphics rendering application, in accordance with certain embodiments of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram depicting a computer system or like device, **40**, that is configured to generate and display interactive 3D graphics, in accordance with certain embodiments of the present invention. Computer system **40** includes at least one processor **42** that is configured to operate in accordance with at least one computer application **44** having computer instructions therein. Processor **42** can include at least one microprocessor or central processing unit (CPU), math co-processors, input/output processors, memory access processors, local memory cache, graphics accelerator processors, etc. A bus **46** is connected to processor **42** and configured to carry data and/or control signals thereto and therefrom. Bus **46** includes one or more buses, and can also include additional communication chip sets, interfaces, gateways, and/or networks.

A primary memory **48**, including at least one frame buffer **50**, is connected to bus **46** and configured to store data and to be accessed by at least processor **42** via bus **46**. Primary memory **48** can also include a plurality of additional memory partitions, buffers, and/or data bases **51**. Primary memory **48** typically includes random access memory (RAM) or the like. A secondary memory **52** is connected to bus **46** and configured to store data and to be accessed by at least processor **42** via bus **46**. Secondary memory **52** can include additional memory and/or a data storage device, such as, for example, a hard disk drive, removable-disk drive, a CD-ROM drive, a DVD-ROM drive, a tape drive, a server, and/or the like. A removable computer-readable media **53** is shown for use with certain types of secondary memory **52**. Media **53** can be, for example, an optical disc (e.g., CD, DVD, etc.), a magnetic disk, a data cartridge, a magnetic tape, or a similar medium configured to store data.

At least one user input device **54** is connected to bus **46** and configured to allow a user to input commands to processor **42** via bus **46**. By way of example, input device **54** can include a keyboard, a mouse, a trackball, a game input, a joy stick, a pen and tablet, a pointing device, a touch screen, a voice recognition device, or other similar devices. At least one output device **56** is connected to bus **46** and configured to display or otherwise output data from processor **42** to the user. For example, output device **56** can include a CRT display, a flat panel display, a LCD display, a plasma display, a television, a projected display, a printer, an imager, etc.

FIG. **2** is a block diagram depicting an exemplary 3D graphics scene **10** that can be rendered by computer system **40** of FIG. **1**. Scene **10** includes at least one 3D object **12** that is arranged within a defined space (e.g., background or backdrop). 3D object **12** is represented by spacial data, for example, a plurality of polygons. When viewed from camera perspective **14**, certain portions of scene **10** will be visible within the field-of-view (fov) associated with the camera and the camera's position and orientation with respect to scene **10**. Camera **14** is typically modeled as being responsive to visible light from scene **10**. As such, scene **10** is illuminated, for example, by one or more light sources, such as, a first light source **16** (#**1**) and a second light source **18** (#**2**). Light source #**1**, in this example, is a uni-directional light source having a particular position, orientation and constrained field-of-view. Light source #**2** is, in this example, a multi-directional light source having a particular position, orientation and non-constrained field-of-view. Light sources #**1** and #**2** are modeled as emitting one or more frequencies of visible light, at an initial intensity (color), onto scene **10**.

A world space coordinate system **20**, for example, having an arbitrary origin and x, y, and z coordinates extending therefrom, is employed to define the spacial relationship between 3D object **10**, light sources **16** and **18**, and camera **14**. Known matrix algebra techniques are used to convert or transform between world space coordinate system **20** and the unique coordinates from the perspectives of light source **16**, light source **18**, and camera **14**. Such techniques are described, for example, in the text by Foley et al.

With this in mind, FIG. **3** is a block diagram depicting exemplary arrangements of modeling data as used to render lighting and shadows, in accordance with certain embodiments of the present invention. For convenience, the various rendered data in FIG. **3** is illustrated as being logically stored in a plurality of 2D matrices or data bases **50** and **51**A–G, each having an X axis and a Y axis. Preferably, and in this example, the X and Y axis correspond an exemplary output device **56** having a screen that displays X by Y number of pixels when provided corresponding red-green-blue (RGB)

pixel data values. Those skilled in the art will recognize that other conventions and/or arrangements can also be used for storing and manipulating the data.

For camera **14**, a camera image **51**A is rendered of scene **10**. Camera image **51**A includes RGB pixel data values from scene **10** for X by Y number of pixels (or pixel groups). An exemplary pixel **60** having camera coordinates SP_x and SP_y is depicted. Associated with camera image **51**A is camera depth **51**B. Camera depth **51**B is a Z-buffer containing depth information for each of the X by Y number of pixels in camera image **51**A. The depth image is used during rendering to correctly determine the ordering of 3D objects within scene **10**, from the camera's perspective. The use of Z-buffers is well known, for example, see Foley et al.

For light source **#1**, a light image **51**C is rendered of scene **10**. Light image **51**C includes RGB pixel data values for the light emitted, for X by Y number of pixels. For example, the data in light image **51**C can represent the intensity, color, and/or pattern of light emitted by light source **#1**. An exemplary pixel **60**', which corresponds to pixel **60** in camera image **51**A, is depicted following transformation as having light source #1 coordinates L_1,P_x and L_1,P_y. Associated with light image **51**C is light depth **51**D. Light depth **51**D is a Z-buffer containing depth information for each of the X by Y number of pixels (or groups of pixels) in light image **51**C. The depth image is used during rendering to correctly determine the ordering of 3D objects within scene **10**, from light source **#1**'s perspective.

Similarly, for light source **#2**, a light image **51**E is rendered of scene **10**. Light image **51**E includes RGB pixel data values for the light emitted, for X by Y number of pixels (or groups of pixels). For example, the data in light image **51**E can represent the intensity, color, and/or pattern of light emitted by light source **#2**. An exemplary pixel **60**", which corresponds to pixel **60** in camera image **51**A, is depicted following transformation as having light source #2 coordinates L_2P_x and L_2P_y. Associated with light image **51**E is light depth **51**F. Light depth **51**F is a Z-buffer containing depth information for each of the X by Y number of pixels in light image **51**E. The depth image is used during rendering to correctly determine the ordering of 3D objects within scene **10**, from light source **#2**'s perspective.

A light accumulation buffer **51**G is also depicted as having pixel data values for X by Y number of pixels (or groups of pixels), as in camera image **51**A and camera depth **51**B. Light accumulation buffer **51**G includes RGB pixel data for the accumulated light falling on a pixel (or groups of pixels) from light sources **#1** and **#2**. As discussed below, by using light. accumulation buffer **51**G, a more realistic shadow rendering can occur, because pixels are accumulatively lighted, rather than accumulatively darkened as in past interactive real time shadow rendering algorithms.

Frame buffer **50** is also depicted as having pixel data values for X by Y number of pixels, as in camera image **51**A, camera depth **51**B, and light accumulation buffer **51**G. Frame buffer **50** includes RGB data of the final rendered 2D image of scene **10**. The data in frame buffer **50** is provided to output device **56** for display to the user. Those skilled in the art will recognize that a plurality of frame buffers can be employed to allow for additional buffering of frames.

A first transformation table (#1) **51**H is also depicted in FIG. **3**. Transformation table #1, is used, in accordance with certain embodiments of the invention to provide for rapid transformation of pixels between camera coordinates and light source #1 coordinates. Transformation table #1 includes X times Y number of entries (locations), preferably arranged to directly corresponding to the sequential memory addresses of the pixel data values in camera image **51**A. When light source **#1** and camera **14** each have fixed positions with respect to one another and/or scene **10**, transformation table **#1** can be precalculated and populated with data using known matrix algebra relationships between the world space coordinate system **20** and the light source **#1** and camera **14** perspectives.

Thus, the resulting transformation table **#1** can be used to quickly determine which, if any, of pixels **60**' (light image) correspond to a specific pixel **60** (camera image).

Similarly a second transformation table (**#2**) **51**I is further depicted in FIG. **3**. Transformation table **#2**, is used, in accordance with certain embodiments of the invention to provide for rapid transformation of pixels between camera coordinates and light source **#2** coordinates. Transformation table **#2** includes X times Y number of entries (locations), preferably arranged to directly corresponding to the sequential memory addresses of the pixel data values in camera image **51**A. When light source **#2** and camera **14** each have fixed positions, transformation table **#2** can be precalculated and populated with data using known matrix algebra relationships between the world space coordinate system **20** and the light source **#2** and camera **14** perspectives. Thus, the resulting transformation table **#1** can be used to quickly determine which, if any, of pixels **60**" (light image) correspond to a specific pixel **60** (camera image).

By using transformation tables **51**H–I, and precalculating the data therein, a substantial amount of processing time is saved when compared to calculating the same data "on-the-fly". This additional cost savings can be especially critical for interactive 3D graphic applications designed to operate on slower, lower-end, and/or older computer systems.

Reference is now made to FIG. **4**, which depicts an exemplary flow-chart for an improved shadow rendering process **100**, in accordance with certain embodiments of the present invention. Process **100** can be implemented, for example, in computer system **40** to render lighting and shadows for scene **10**. In step **102**, the camera's view is rendered using conventional methods, thereby producing camera image **51**A and camera depth **51**B. In step **104**, the view from a light source is rendered. For example, in step **104**, rendering the view from light source **#1** produces light **#1** image **51**C and light **#1** depth **51**D.

Next, in step **106**, a pixel **60** in camera image **51**A is transformed or is otherwise used to determine a corresponding pixel **60**' in light **#1** image **51**C (and light **#1** depth **51**D). The transformation calculations needed to move between coordinates in step **106** can be precalculated and stored, for example, in transformation table **#1** provided that camera **14** and light source **#1** are fixed with respect to scene **10**. Alternatively, such transformation calculations can be conducted on-the-fly provided adequate processing capability. If either camera **14** or light source **#1** are not fixed with respect to scene **10**, then the transformation calculations can be conducted on-the-fly (i.e., in real-time between frames).

In step **108**, if the transformed pixel identified in step **106** is illuminated by the light source, then the corresponding pixel data value in the light image is added to the light accumulation buffer **51**G. For example, considering pixel **60**', from the Z-value associated with pixel **60**' (as identified in light **#1** depth **51**D) it can be determined if pixel **60**' is lighted by, or shaded from, light source **#1**. If pixel **60**' is lighted, then the corresponding (RGB) pixel data value from light **#1** image **51**C is added to light accumulation buffer **51**G. If pixel **60**' is not-lighted (i.e., is shaded), then no change is made to light accumulation buffer **51**G.

Steps **106** and **108** are repeated for each of the pixels in camera image **51**A, as depicted by the iteration provided by step **110**. After all of the pixels in camera image **51**A have been processed in steps **106-110**, then, according to step **112**, the process is repeated for each additional light source. Step **112** leads back to step **104**, wherein the next light source view is rendered. For example, steps **104–110** can be repeated again for light source #**2** (or #N light sources). This iterative process allows for each of the pixel data values within light accumulation buffer **51**G to be incrementally increased in a manner that matches the cumulative light cast by the multiple light sources on each pixel.

After each of the light sources has been processed in accord with steps **104** through **112**, then in step **114**, a pixel data value from camera image **51**A is multiplied by a corresponding pixel data value from light accumulation buffer **51**G and the results are stored in camera image **51**A. Step **114** is repeated for each of the pixels in camera image **51**A, as depicted by iterative step **116**. Then, in step **118**, a resulting camera image **51**A is further rendered in accord with other processes, as needed, and eventually stored in frame buffer **50** and displayed as a frame of data.

Process **100**, therefore, in accordance with certain aspects of the present invention, provides realistic lighting and shadow rendering while also being computationally efficient. Process **100** can be adapted for a plurality of light sources, either fixed or moving, and for changing camera views. By way of example, the following exemplary pseudocode can be implemented in either hardware of software to provide for process **100**:

```
RENDER EACH VIEW (PARTIAL IF THE LIGHT IS
  STATIONARY)
CLEAR ACCUM BUFFER
FOR EACH LIGHT SOURCE . . .
  FOR EACH PIXEL IN CAMERA IMAGE SP_X SP_Y . . .
    TRANSFORM EACH SP TO A LP {LIGHT PIXEL}
      USING EITHER:
      TRANSFORM LOOK-UP TABLE,
         OR
      MATRIX TRANSFORMATION CALCULATION
      IF LP_Z<LIGHT DEPTH (LP_X, LP_Y) THEN
      ACCUM (SP_X, SP_Y)+=LIGHT IMAGE (LP_X, LP_Y)
  FOR EACH PIXEL IN CAMERA IMAGE . . .
    CAMERA IMAGE (SP_X, SP_Y)*=ACCUM (SP_X, SP_Y)
```

The flow-chart in FIG. **5** depicts an exemplary process **120** that can be included in step **106**. Process **120** includes step **122**, wherein an applicable transformation table is used to determine the transformation from camera to light source viewpoints when the camera and light source are fixed with respect to scene **10**. Otherwise, in step **124**, if the camera or light source are not fixed then a matrix transformation algorithm is used.

An exemplary process **130** is depicted in the flow-chart of FIG. **6**. Process **130** can be used to precalculate transform tables and/or included in step **124** calculate the transform on-the-fly. In step **132**, a transformation is made from world space coordinate system **20** to camera coordinates. Next, in step **134**, a transformation is made from camera coordinates to light source coordinates. These types of transformation processes, which are preferably completed using standard matrix algebra, are well known to those skilled in the art (see, e.g., Foley et al. text). In step **136**, the resulting transformation data (camera to light source) is provided in a translation table per step **138**, or returned to the shadow rendering process per step **140**.

FIGS. **7**A–D depict actual computer screen shots for an exemplary 3D scene of an interactive real time graphics rendering application, having an improved shadow rendering capability as described above and configured for a PC, in accordance with certain embodiments of the present invention. The application that generated the images depicted in FIGS. **7**A–D is a computer-based interactive adventure game. In the exemplary scenes, the camera and two light sources are each fixed with respect to the scene. The frame in FIG. **7**A is a monochrome photocopy of the colored rendered scene. The frame of FIG. **7**A is shown inverted in FIG. **7**B to further highlight the shadowing rendered in the scene. FIG. **7**C is a essentially a "behind the scenes" view of various image buffers that are used to generate the image of FIG. **7**A. FIG. **7**D is the inverted image of FIG. **7**C.

Reference will first be made to the image in FIG. **7**A, with reference numerals being added to the inverted image of FIG. **7**B and/or the fully lighted image of FIGS. **7**C–D. In FIG. **7**A there is depicted a portion of a room **200** having texture mapped walls **202**A–D, floor **204**, and ceiling **205**. One of the walls **202**B has a large mirror **203**, in which is shown the reflection from another wall **202**D having several pictures hanging thereon. Additional 3D objects within the room include torches **206**A and **206**B mounted on side walls, **202**A and **202**C, respectively. A man **208** is shown standing on floor **204** and in front of the mirrored wall **202**B. Light is being reflected onto a portion of the mirrored wall **202**B, the floor **204**, the man **208**, and on the wall **202**D having pictures hanging thereon. The man **208** casts a shadow **210** onto a portion of the floor **204** and the mirrored wall **202**B.

The frame in FIG. **7**A, and in particular, the lighting rendered in the scene is demonstrated by the additional images in FIG. **7**C. Room **200'** is depicted in full light in FIG. **7**C. From this image of room **200'**, one can understand the configuration of the modeled 3D world. Refer to the inverted image of FIG. **7**D, as required, to identify a specific reference. FIG. **7**C also includes four other images that are used to render the lighting and shadows in room **200'**.

There are two light sources that are not visible within room **200'**. These light sources are used to simulate the light emitted by simulated torches **206**A and **206**B. These light sources, which are not shown in FIG. **7**C, are directional light sources having fixed positions with respect to room **200**. Image **220** represents the light depth data for the first light, which has a circular field of view (or aperture) and is positioned to shine light on a portion of floor **204** and mirrored wall **202**B. The information depicted in image **220** corresponds to depth, for example, as stored in a Z-buffer associated with this particular light source. Within depth image **220**, as depicted in FIG. **7**C, the closer a pixel is to the light source, the darker its image. Thus, for example, the man **208** in FIG. **7**C is closest to the light source and as such is rendered the darkest shade. Conversely, the interface (corner) of mirrored wall **202**B and floor **204** is the farthest away from the light source and as such is rendered the lightest shade. This is just one convention, obviously the convention could be reversed in other systems. Note, that the image **220** in FIG. **7**D is inverted and thus so to is the convention.

Also associated with the first light source is a light image **224**. In this example, light image **224** includes a graduated pattern of intensity that is highest near the center and lowest near the edges. In this example, light image **224** is essentially a light filter based on a cosine function. It is intended, however, that the RGB pixel data values in a light image can include any pattern of RGB data, including static and dynamically changing patterns. For example, in accordance with certain embodiments of the present invention, a light

image can include a dynamically changing graphical image. This can be used to simulate light that is reflected from changing surfaces, such as, for example, the light reflected from a rippling body of water. By dynamically changing the light image using a recorded or simulated image of such a body of water, the light source will essentially paint the scene with a rippling light. Taken a further step, the light image can include an animation, motion picture or similar video image that is projected, not unlike a movie projector, on to the various surfaces of the scene. Indeed, this can be used to model a movie projector, wherein 3D objects, such as man **208** can walk in front of the projected light image and have portions of the projected image fall on his body.

With regard to man **208** as depicted in depth image **220**, the depth image **220** has been further processed in this example to include data relating to the depth of man **208**. This can be accomplished, for example, by comparing previous frames and completing new transform calculations for pixels that have changed and that are in the depth image for the light source. Thus, for example, from the previous frame, man **208** may have moved slightly (e.g., in response to inputs from the user). A portion of the pixels are identified as having changed from the previous frame. The portion of the pixels that changed are then transformed and processed to generate new modified light depth data **228**. In this manner, only those portions of the scene that change need to be reprocessed.

For the second light source, a depth image **222** and light image **226** are also provided. Depth image **222** demonstrates that the second light source is positioned facing wall **202**D and casting light on a portion of floor **204** and wall **202**D. Light image **226** is similar to light image **224**. Note that depth image **222** does not include man **208** or any other moving 3D object at this time. Thus, depth image **222** need not be updated at this time.

The various images in FIG. **7**C are processed in accordance with process **100**. A light accumulation buffer and subsequent frame buffer are created by combining data from the image of room **200**', and light images **224** and **226**, in accordance with the data in depth images **220** and **222**. The resulting frame buffer is that of FIG. **7**A, which clearly shows that man **208** casts a single shadow **210** as a result of the first light. Additionally, the accumulated light on mirrored wall **202**B and **202**D are shown.

In accordance with still further embodiments of the present invention, if camera **14** is required to periodically change position with respect to scene **10**, for example, during an interactive simulation, then process **120** is repeated as necessary to recalculate and update the applicable transform tables, or to generate different, additional transform tables, based on the new camera position. If the camera is continually moving with respect to scene **10**, then rather than manipulating and accumulating light based on pixels, process **100** is adapted to manipulate groups of pixels and/or polygons. This allows for a more granular approach, in which a light image can be rendered for each polygon, and light accumulation buffers can be used to accumulate light intensities from the various light sources for each polygon, rather than for each screen pixel. As such, a plurality of light images can be precomputed, one for each of the polygons (or for groups of polygons), for each of the fixed lights.

Although several preferred embodiments of the methods and arrangements of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

What is claimed is:

1. A shadow rendering method for use in a computer system, the method comprising the steps of:

providing observer data of a simulated multi-dimensional scene;

providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;

for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in a light accumulation buffer; and then

combining at least a portion of said light accumulation buffer with said observer data; and

displaying resulting image data to a computer screen.

2. The method as recited in claim **1**, wherein said observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

3. The method as recited in claim **2**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said computer screen, such that said observed color data includes an observed red-green-blue value for said pixel and said observed depth data includes an observed z-buffer value for said pixel.

4. The method as recited in claim **2**, wherein said lighting data includes source color data associated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives.

5. The method as recited in claim **4**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said computer screen, such that said source color data includes a source red-green-blue value for said pixel and said source depth data includes a source z-buffer value for said pixel.

6. The method as recited in claim **4**, wherein the step of comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source further includes comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source.

7. The method as recited in claim **6**, wherein the step of comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source further includes converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives, before comparing said observed depth data with said source depth data.

8. The method as recited in claim **7**, wherein the step of converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives further includes using a precalculated matrix transformation look-up table for at least one of said plurality of light sources, when said light source has a fixed perspective of said scene.

9. The method as recited in claim **4**, wherein at least a portion of said source color data is selectively controlled source color data that can be changed over a period of time during which at least the step of displaying resulting image data to said computer screen is repeated a plurality of times.

10. The method as recited in claim **9**, wherein said controlled source color data includes data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

11. An arrangement configured to render shadows in a simulated multi-dimensional scene, the arrangement comprising:

a display screen configured to display image data;

memory for storing data including observer data associated with a simulated multi-dimensional scene, and lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data, said memory further including a light accumulation buffer portion and a frame buffer portion;

at least one processor coupled to said memory and said display screen and operatively configured to, for each of said plurality of light sources, compare at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in said light accumulation buffer, then combining at least a portion of said light accumulation buffer with said observer data, and displaying resulting image data in said frame buffer, and outputting at least a portion of said image data in said frame buffer to said display screen.

12. The arrangement as recited in claim **11**, wherein said observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

13. The arrangement as recited in claim **12**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said display screen, such that said observed color data includes an observed red-green-blue value for said pixel and said observed depth data includes a observed z-buffer value for said pixel.

14. The arrangement as recited in claim **12**, wherein said lighting data includes source color data associated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives.

15. The arrangement as recited in claim **14**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said display screen, such that said source color data includes a source red-green-blue value for said pixel and said source depth data includes a source zbuffer value for said pixel.

16. The arrangement as recited in claim **14**, wherein said processor is further configured to compare at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source.

17. The arrangement as recited in claim **16**, wherein said processor is further configured to convert at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives, before comparing said observed depth data with said source depth data.

18. The arrangement as recited in claim **17**, wherein said memory further includes at least one precalculated matrix transformation table associated with at least one of said plurality of light sources, and said processor is further configured to use said precalculated matrix transformation look-up table when said light source is simulated as having a fixed perspective of said scene.

19. The arrangement as recited in claim **14**, wherein said processor is further configured to selectively control at least a portion of said source color data over a period of time.

20. The arrangement as recited in claim **19**, wherein said controlled source color data includes data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

21. A method for simulating light falling on a modeled object in a computer generated multi-dimensional graphics simulation, the method comprising the steps of:

for a simulated camera, rendering a camera view of at least one modeled object that is at least partially optically opaque, to produce a camera depth array comprising camera depth data values and a corresponding camera image array comprising camera image data values;

for a first simulated light, rendering a first light view of said modeled object to produce a first light depth array comprising first light depth data values and a corresponding first light image array comprising first light image data values;

transforming at least a portion of said camera depth data values to said first light view, thereby generating a first transformed camera array comprising first transformed camera depth data values;

for each data value therein, comparing said first light depth array to said first transformed camera array to determine if said data value in said first light depth array is closer to said first simulated light, and if so, adding a corresponding data value from said first light image array to a light accumulation array comprising light accumulation data values; and

for each data value therein, multiplying said camera image array by a corresponding data value from said light accumulation array to produce a lighted camera image array comprising lighted camera image values.

22. The method as recited in claim **21**, wherein, prior to the step of multiplying said camera image array by a corresponding data value from said light accumulation array to produce a lighted camera image array, the method further includes the steps of:

for a second simulated light, rendering a second light view of said modeled object to produce a second light depth array comprising second light depth data values and a corresponding second light image array comprising second light image data values;

transforming at least a portion of said camera depth data values to said second light view, thereby generating a second transformed camera array comprising second transformed camera depth data values; and

for each data value therein, comparing said second light depth array to said second transformed camera array to determine if said data value in said second light depth array is closer to said second simulated light, and if so, adding a corresponding data value from said second light image array to said light accumulation array.

23. The method as recited in claim **21**, wherein each of said camera depth values includes z-buffer data associated with a different pixel selected from a plurality of pixels on a computer display screen.

24. The method as recited in claim **23**, wherein each of said first light depth values includes z-buffer data associated with a different pixel selected from a plurality of pixels on a computer display screen.

25. The method as recited in claim **21**, wherein each of said camera depth values includes z-buffer data associated with a different set of pixels selected from a plurality of pixels on a computer display screen.

26. The method as recited in claim **25**, wherein each of said first light depth values includes z-buffer data associated with a different set of pixels selected from a plurality of pixels on a computer display screen.

27. The method as recited in claim **21**, wherein said camera image data and said first light image data each include color data associated with at least one pixel on a computer screen.

28. The method as recited in claim **21**, further comprising the steps of:

repeating the steps recited in claim **21** at a frame rate; and

sequentially displaying a plurality of frames of data on a computer screen at said frame rate, wherein subsequent frames of data include subsequently processed lighted camera image data, and wherein said step of rendering said first light view further comprises dynamically changing at least one of said first light image data values between said subsequent frames of data.

29. The method as recited in claim **28** wherein at least a portion of said first light image data values represent dynamically changing color data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

30. The method as recited in claim **28**, wherein said frame rate is at least about **25** frames per second.

31. The method as recited in claim **21**, wherein the step of transforming at least a portion of said camera depth values to said first light view further includes the step of transforming said camera depth array from a camera coordinate system to a corresponding first light coordinate system.

32. The method as recited in claim **31**, wherein the step of transforming said camera depth array from a camera coordinate system to a corresponding first light coordinate system further includes the step of using a precalculated transformation table to transform directly from said camera coordinate system to said corresponding first light coordinate system.

33. A computer-readable medium carrying at least one set of computer instructions configured to cause a computer to operatively simulate light falling on a modeled object in a computer generated multi-dimensional graphics simulation by performing operations comprising:

a) rendering an observer view of at least a portion of a spatially modeled object as a plurality of observed depth values and observed image values;

b) rendering a source view of at least a portion of said modeled object as a plurality of source depth values and a plurality of source image values;

c) transforming at least a portion of said observed depth values to said source view;

d) modifying at least one image accumulation value with one of said observed image values if said corresponding transformed observer value is equal to a comparable one of said source depth values;

e) multiplying said one of said observed image values by said at least one image accumulation value to produce at least one pixel value; and

f) displaying said pixel value on a computer screen.

34. The computer-readable medium as recited in claim **33**, further configured to cause the computer to perform the further step of:

g) following step d), repeating steps b) through d) for at least one additional source view.

35. The computer-readable medium as recited in claim **34**, further configured to cause the computer to perform the further steps of:

h) repeating steps a) through g) a frame rate; and

wherein step f) further includes sequentially displaying a plurality of pixels as frames of data on said computer screen at said frame rate, and said step of rendering said source view further includes changing at least one of said source image values between said subsequent frames of data.

36. The computer-readable medium as recited in claim **35** wherein at least a portion of said source image values represent color data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

37. The computer-readable medium as recited in claim **35**, wherein step c) further includes transforming at least a portion of said observed depth values from an observer coordinate system to a corresponding source coordinate system.

38. The computer-readable medium as recited in claim **37**, wherein the step of transforming at least a portion of said observed depth values from an observer coordinate system to a corresponding source coordinate system further includes using a precalculated transformation table to transform directly from said observer coordinate system to said corresponding source coordinate system.

39. A computer-readable medium carrying at least one set of computer instructions configured to cause at least one processor within a computer system to operatively render simulated shadows in a multi-dimensional simulated scene by performing the steps of:

providing observer data of a simulated multi-dimensional scene;

providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;

for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in a light accumulation buffer; and then

combining at least a portion of said light accumulation buffer with said observer data; and

displaying resulting image data to a computer screen.

40. The computer-readable medium as recited in claim **39**, wherein said observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

41. The computer-readable medium as recited in claim **40**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said computer screen, such that said observed color data includes an observed red-green-blue value for said pixel and said observed depth data includes a observed z-buffer value for said pixel.

42. The computer-readable medium as recited in claim **40**, wherein said lighting data includes source color data asso-

ciated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives.

43. The computer-readable medium as recited in claim **42**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said computer screen, such that said source color data includes a source red-green-blue value for said pixel and said source depth data includes a source z-buffer value for said pixel.

44. The computer-readable medium as recited in claim **42**, wherein the step of comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source further includes comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source.

45. The computer-readable medium as recited in claim **44**, wherein the step of comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source further includes converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives, before comparing said observed depth data with said source depth data.

46. The computer-readable medium as recited in claim **45**, wherein the step of converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives further includes using a precalculated matrix transformation look-up table for at least one of said plurality of light sources, when said light source has a fixed perspective of said scene.

47. The computer-readable medium as recited in claim **42**, wherein at least a portion of said source color data is selectively controlled source color data that can be changed over a period of time during which at least the step of displaying resulting image data to said computer screen is repeated a plurality of times.

48. The computer-readable medium as recited in claim **47**, wherein said controlled source color data includes data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

* * * * *

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Randel

(10) **Patent No.: US 7,061,488 B2**
(45) **Date of Patent: Jun. 13, 2006**

(54) **LIGHTING AND SHADOWING METHODS AND ARRANGEMENTS FOR USE IN COMPUTER GRAPHIC SIMULATIONS**

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(73) Assignee: **Terminal Reality, Inc.**, Lewisville, TX (US)

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Related U.S. Application Data

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(51) **Int. Cl.**
G06T 17/00 (2006.01)

(52) **U.S. Cl.** **345/426**
(58) **Field of Classification Search** 345/418, 345/419, 425, 426, 427
See application file for complete search history.

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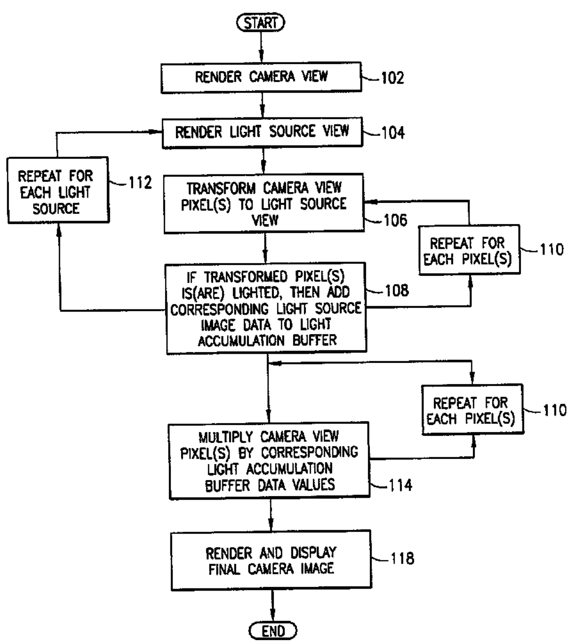
(74) *Attorney, Agent, or Firm*—Morgan, Lewis & Bockius, LLP

(57) **ABSTRACT**

The effects of lighting and resulting shadows within a computer simulated three-dimensional scene are modeled by rendering a light depth image and a light color image for each of the light sources. The light depth images are compared to a camera depth image to determine if a point within the scene is lighted by the various light sources. An accumulated light image is produced by combining those portions of the light color images determined to be lighting the scene. The resulting accumulated light image is then combined with a camera color image to produce a lighted camera image that can be further processed and eventually displayed on a computer display screen. The light color image can be static or dynamic. Transformations between different perspective and/or coordinate systems can be pre-calculated for fixed cameras or light sources. The various images and manipulations can include individual pixel data values, multiple-pixel values, polygon values, texture maps, and the like.

62 Claims, 6 Drawing Sheets



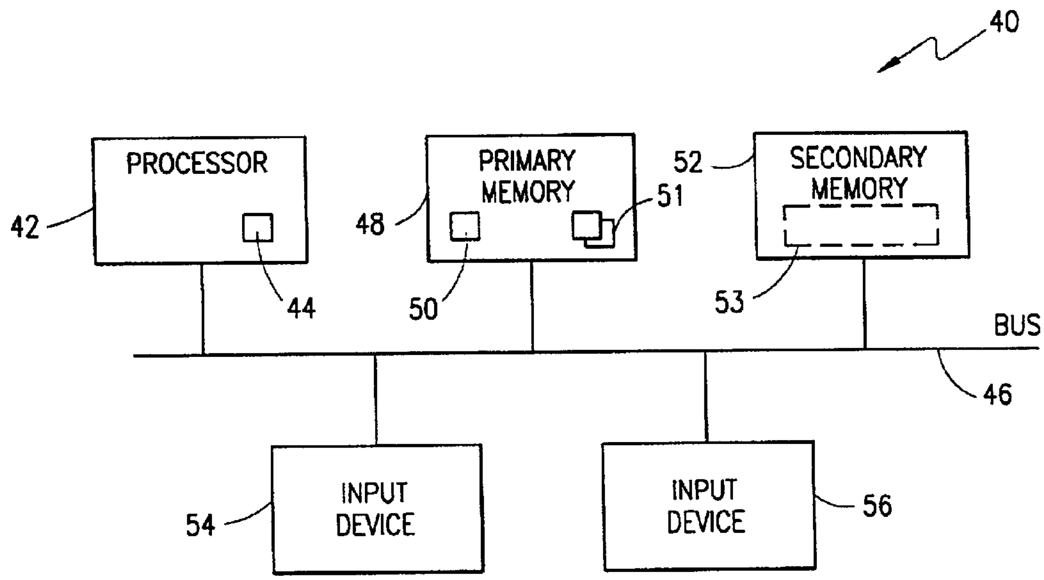

40
PROCESSOR
42
44
PRIMARY MEMORY
48
50
51
52
SECONDARY MEMORY
53
BUS
46
INPUT DEVICE
54
INPUT DEVICE
56

FIG. 1

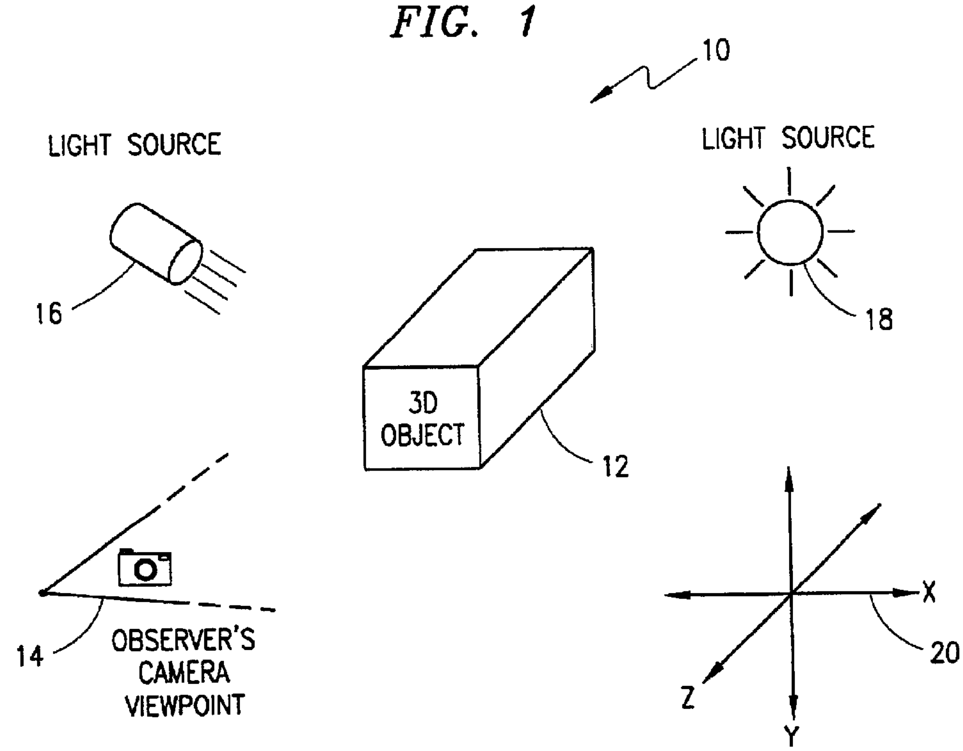

10
LIGHT SOURCE
16
LIGHT SOURCE
18
3D OBJECT
12
14
OBSERVER'S CAMERA VIEWPOINT
X
Y
Z
20

FIG. 2

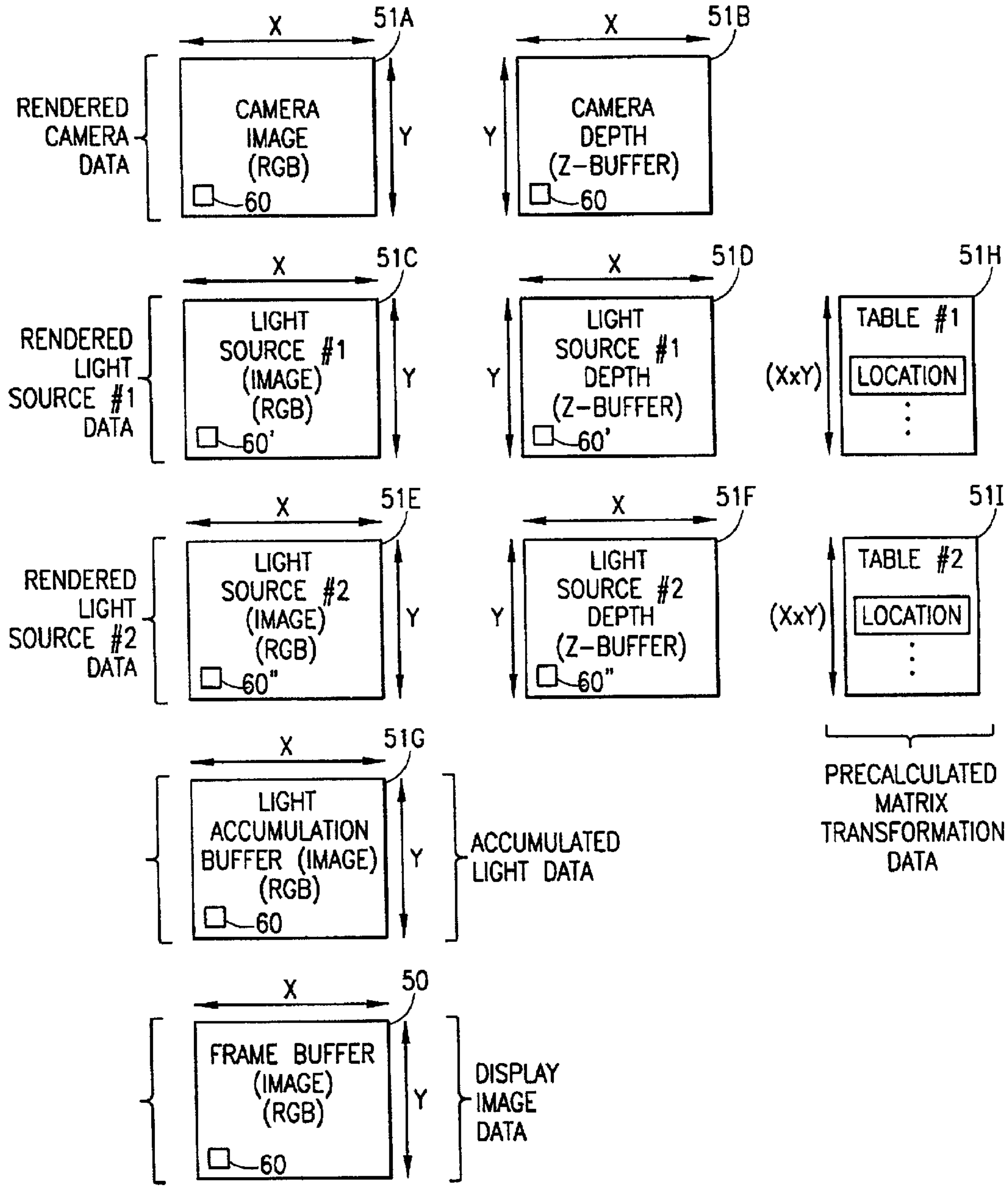

51A
X
Y
RENDERED CAMERA DATA
CAMERA IMAGE (RGB)
60
51B
CAMERA DEPTH (Z-BUFFER)
60
51C
RENDERED LIGHT SOURCE #1 DATA
LIGHT SOURCE #1 (IMAGE) (RGB)
60'
51D
LIGHT SOURCE #1 DEPTH (Z-BUFFER)
60'
51H
(XxY)
TABLE #1
LOCATION
51E
RENDERED LIGHT SOURCE #2 DATA
LIGHT SOURCE #2 (IMAGE) (RGB)
60"
51F
LIGHT SOURCE #2 DEPTH (Z-BUFFER)
60"
51I
TABLE #2
LOCATION
PRECALCULATED MATRIX TRANSFORMATION DATA
51G
LIGHT ACCUMULATION BUFFER (IMAGE) (RGB)
60
ACCUMULATED LIGHT DATA
50
FRAME BUFFER (IMAGE) (RGB)
60
DISPLAY IMAGE DATA

FIG. 3

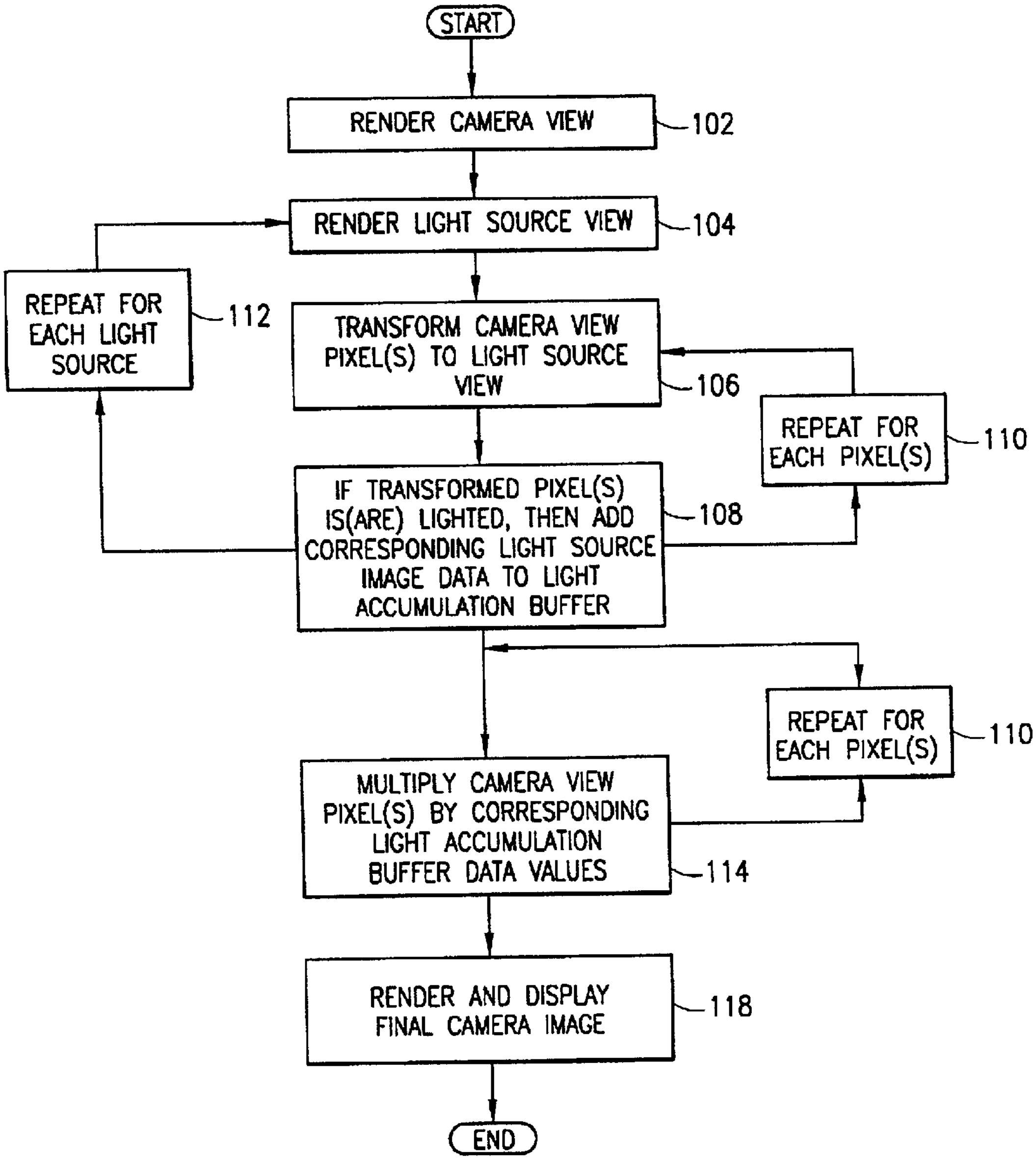

START
RENDER CAMERA VIEW
102
RENDER LIGHT SOURCE VIEW
104
REPEAT FOR EACH LIGHT SOURCE
112
TRANSFORM CAMERA VIEW PIXEL(S) TO LIGHT SOURCE VIEW
106
REPEAT FOR EACH PIXEL(S)
110
IF TRANSFORMED PIXEL(S) IS(ARE) LIGHTED, THEN ADD CORRESPONDING LIGHT SOURCE IMAGE DATA TO LIGHT ACCUMULATION BUFFER
108
REPEAT FOR EACH PIXEL(S)
110
MULTIPLY CAMERA VIEW PIXEL(S) BY CORRESPONDING LIGHT ACCUMULATION BUFFER DATA VALUES
114
RENDER AND DISPLAY FINAL CAMERA IMAGE
118
END

FIG. 4

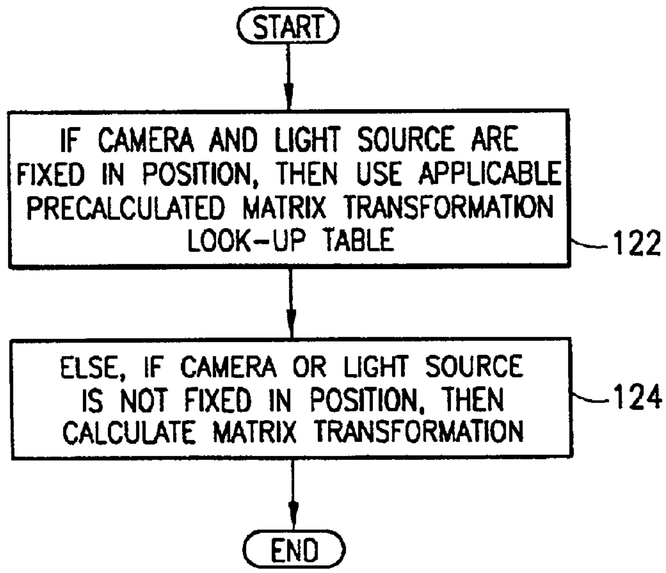

START
IF CAMERA AND LIGHT SOURCE ARE FIXED IN POSITION, THEN USE APPLICABLE PRECALCULATED MATRIX TRANSFORMATION LOOK-UP TABLE
122
ELSE, IF CAMERA OR LIGHT SOURCE IS NOT FIXED IN POSITION, THEN CALCULATE MATRIX TRANSFORMATION
124
END

FIG. 5

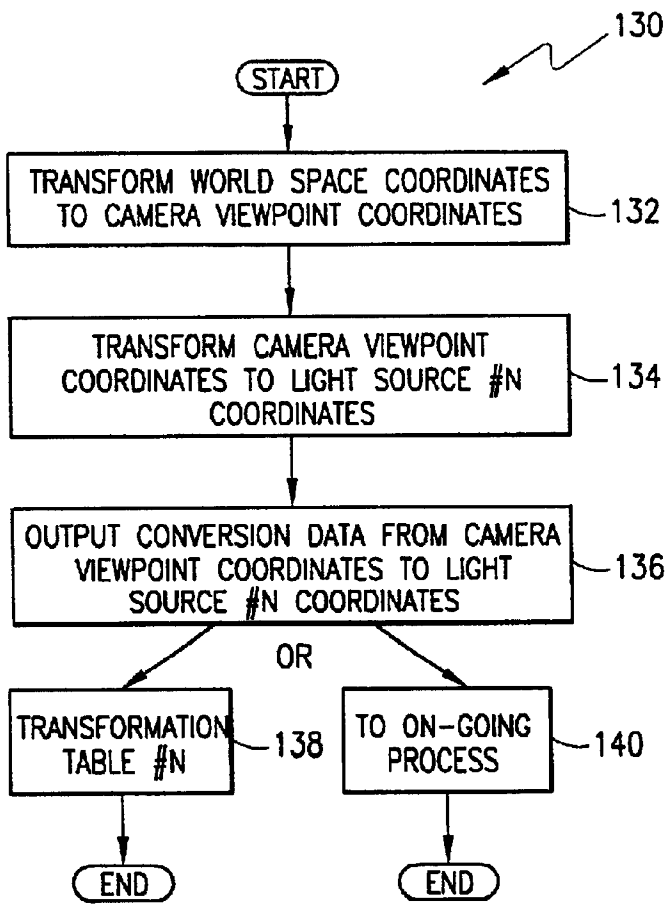

130
START
TRANSFORM WORLD SPACE COORDINATES TO CAMERA VIEWPOINT COORDINATES
132
TRANSFORM CAMERA VIEWPOINT COORDINATES TO LIGHT SOURCE #N COORDINATES
134
OUTPUT CONVERSION DATA FROM CAMERA VIEWPOINT COORDINATES TO LIGHT SOURCE #N COORDINATES
136
OR
TRANSFORMATION TABLE #N
138
TO ON-GOING PROCESS
140
END
END

FIG. 6

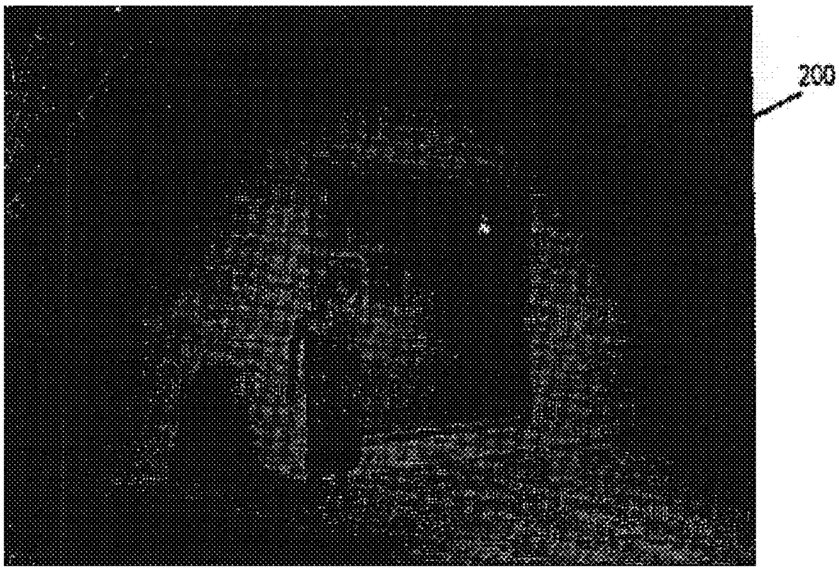

200

FIG. 7A

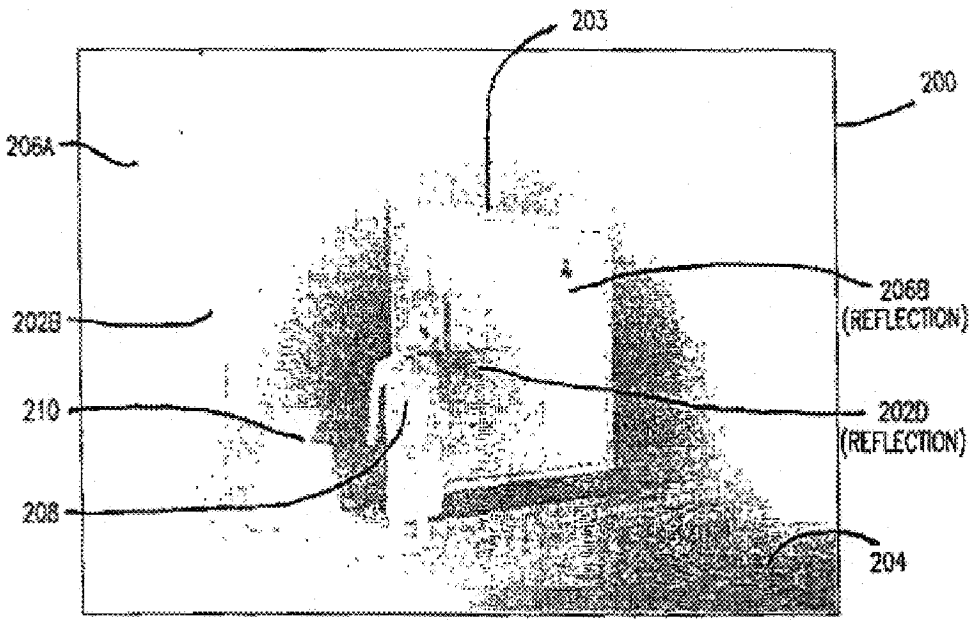

203
200
206A
206B
(REFLECTION)
202B
210
202D
(REFLECTION)
208
204

FIG. 7B

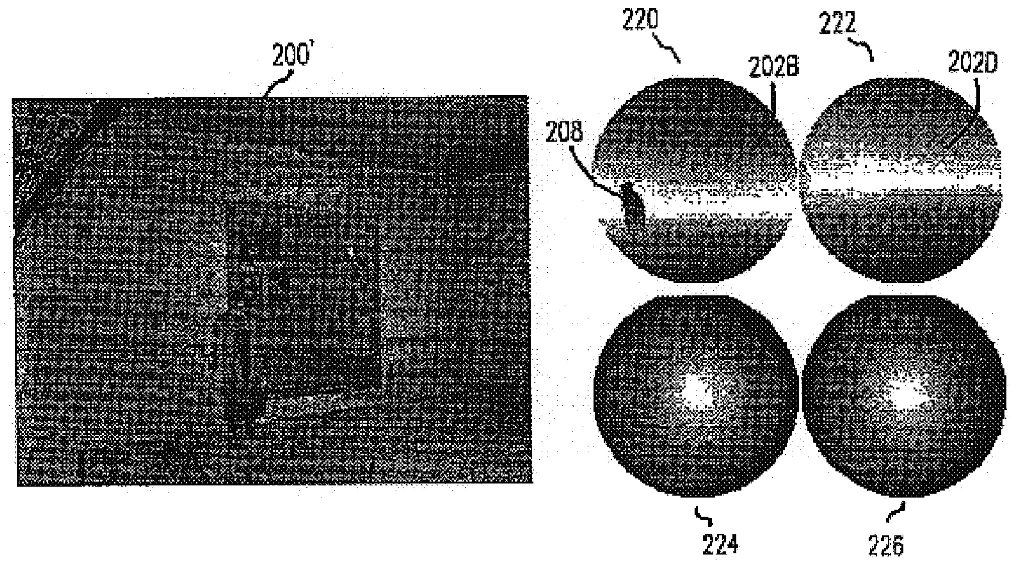

200'
220
222
202B
202D
208
224
226

FIG. 7C

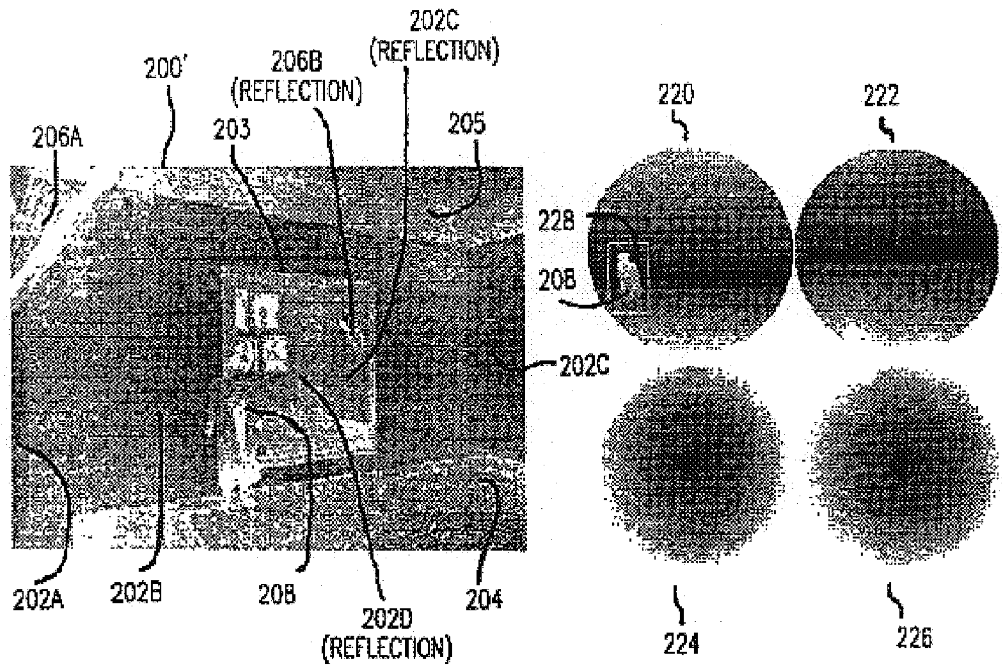

202C
(REFLECTION)
206B
(REFLECTION)
200'
206A
203
205
220
222
228
208
202C
202A
202B
208
202D
(REFLECTION)
204
224
226

FIG. 7D

LIGHTING AND SHADOWING METHODS AND ARRANGEMENTS FOR USE IN COMPUTER GRAPHIC SIMULATIONS

This application is a continuation of application Ser. No. 09/268,078, filed on Mar. 12, 1999, now U.S. Pat. No. 6,362,822.

TECHNICAL FIELD OF THE INVENTION

The present invention relates to computer graphics and, more particularly, to improved methods and arrangements f or use in rendering lighting and shadows in computer graphic simulations, such as, for example, interactive computer graphics simulations of multi-dimensional objects.

BACKGROUND

Computer generated graphics are becoming more popular in everyday computing especially given recent advances in affordable computer hardware and software. This trend is expected to continue in the foreseeable future. By way of example, interactive computer generated graphical images are becoming increasingly detailed and more realistic due to increased processing capabilities in personal computers (PCs). No where is this more evident than in the computer gaming arena, wherein virtual three-dimensional (3D) worlds are created in software and interactively explored by the computer's user.

As with the real World, these virtual 3D worlds consist of a plurality of 3D objects. These 3D objects are typically modeled by one or more polygons. In the computer, depending upon the orientation of the scene being viewed, some of these polygons correspond to individual pixels that are displayed on the computer's display screen. Within the computer, these pixels are represented by data that can be manipulated and stored in at least one data base. For example, once the arrangement of these 3D objects with respect to one another has been determined for a particular viewpoint, the rendered scene of the 3D world is projected onto a two-dimensional (2D) frame that can be displayed to the user. The frame is typically a data base that contains pixel color information with regard to the display screen.

A sense of motion within this virtual 3D world is provided by incrementally altering the arrangement of these 3D objects and quickly re-displaying the transformed frame. Typically, a frame rate of at least about twenty-five (25) frames-per-second (fps) is desired to convey a sense of motion.

Rendering such interactive 3D worlds, however, typically requires that millions of calculations be conducted between frames (i.e., in "real time"). Since there is a limit to the amount of processing that a computer can provide between frames, simplifications or other compromises often need to be made in modeling a 3D world. Additionally, advanced algorithms are implemented in either hardware and/or software to further streamline the processing of the resulting 3D scene and 2D images. Regardless of how the rendering computations are completed, the goal remains the same, namely, to provide a realistic, interactive virtual 3D world to the user.

One of the unfortunate compromises made in the past, has been in the area of lighting and, more particularly, in the area of rendering shadows cast by lighted 3D objects. Many shadow rendering processes have been considered to be too compute intensive for most lower-end computer applications, and as such shadow rendering is often ignored or otherwise greatly simplified. Several advanced and simplified shadow rendering algorithms and other graphical algorithms and techniques are described by James D. Foley, et al. in *Computer Graphics: Principles and Practice,* second edition, 1997 (ISBN 0-201-84840-6), published by Addison-Wesley Publishing Company, Inc. This text is expressly incorporated herein, by reference, in its entirety and for all purposes.

By way of a particular example, Foley et al. describe a promising two-pass object-precision shadow algorithm in Section 16.4.2 of the text. This two-pass shadow algorithm, developed by Atherton, Weiler and Greenberg, essentially determines which portions on a 3D object's surfaces are visible from the perspective of a light source (i.e., from the light source's view point). This requires converting the data for the 3D object, as represented in a data base, from a modeled world coordinate to a light source coordinate and then determining which portions of the various polygons are visible surfaces with respect to the light source, for example, using a hidden-surface removal algorithm. Since these visible portions are illuminated (i.e., lit) by the light source, the remaining portions (i.e., the hidden-surfaces) are darkened as being shaded from the light. The resulting data is then transformed back to modeling world coordinates and merged with the original object data base. This creates a viewpoint-independent merged data base that can be used to determine the shadows on the various 3D objects from any other viewpoint. This is the first step of the two-step shadow algorithm.

In the second step of the two-pass shadow algorithm, the data in the merged data base is then converted from the modeled world space to a corresponding screen (or camera) viewpoint. Then, a hidden-surface algorithm is used to determine which portions of the various polygons are visible surfaces with respect to the camera. These visible portions are identified as being visible to the camera and as being either not-darkened (i.e., lit) or darkened (i.e., in a shadow). A polygon scan-conversion algorithm is then used to render the resulting 2D image.

One of the drawbacks to this type of shadow algorithm is that unrealistic shadowing can occur in scenes having multiple light sources. Foley et al. for example, one page 747 of their text, teach that multiple light sources are handled by re-processing the merged data base for each new light source. Thus, for example, assume that a portion of a polygon which is visible from the camera viewpoint has been darkened because it is shaded from a first light source. This is information is recorded in the merged data base. Then, this merged data base is used as the starting point for a similar process for the second light source's viewpoint determination. As part of this second light source's viewpoint determination, additional darkening can occur to portions of the scene that are also shaded from the second light source. As a result, there is a potential for a portion of the scene to be darkened twice. In scenes having multiple light sources, including ambient light, this additive darkening of portions, and in particular, pixels, tends to reduce the realism of the shadowing effects and can lead to awkward shadowing cross-talk, wherein a shadow is made overly dark and has unrealistic transitions. This is especially true for applications using a "stencil buffer" technique for shadowing.

Additionally, when there are several light sources, for example, four or more, the transformation process associated with converting between the camera, world, and light viewpoints in support of this type of two pass algorithm can prove to be too burdensome, thereby inhibiting or otherwise diminishing the effectiveness of the resulting interactive real-time graphics.

Consequently, there is need for improved shadow rendering methods and arrangements. Preferably, the improved shadow rendering methods and arrangements support real time interactive graphics on conventional PCs and the like, and allow for multiple light sources to be modeled in a more efficient and realistic manner.

SUMMARY OF THE INVENTION

In accordance with certain aspects of the present invention, improved lighting and shadow rendering methods and arrangements are provided. These improved lighting and shadow rendering methods and arrangements can be implemented to support real time interactive graphics on conventional computers such as personal computers (PCs), computer gaming devices and the like. These improved methods and arrangements allow for multiple light sources to be modeled in a more efficient and realistic manner without becoming overly burdensome, or otherwise inhibiting or diminishing the effectiveness of the resulting interactive real time graphics.

For example, the above stated needs and others are met by a shadow rendering method for use in a computer system, in accordance with certain embodiments of the present invention. The method includes the steps of providing observer data of a simulated multi-dimensional scene and providing lighting data associated with a plurality of simulated light sources arranged to illuminate the scene. This lighting data includes light image data, for example. For each of the light sources, the method then includes the steps of comparing at least a portion of the observer data with at least a portion of the lighting data to determine if a modeled point within the scene is illuminated by the light source, and storing at least a portion of the light image data associated with the point and the light source in a light accumulation buffer. Once this is completed, the method includes the steps of combining at least a portion of the light accumulation buffer with the observer data, and displaying the resulting image data to a computer screen.

In accordance with certain further embodiments of the present invention, the observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within the scene as rendered from an observer's perspective. Thus, for example, the modeled polygons can be associated with a single pixel on the computer screen or a group of pixels, wherein the observed color data includes an observed red-green-blue value for the pixel(s) and the observed depth data includes an observed z-buffer value for the pixel(s). Similar data is provided for the lighting data, wherein, in certain embodiments, the lighting data includes source color data associated with at least one of the light sources and source depth data associated with the plurality of modeled polygons within the scene as rendered from a plurality of different light source's perspectives.

In accordance with still further embodiments of the above method, at least a portion of the observed depth data is compared with at least a portion of the source depth data to determine if the modeled point is illuminated by the light source. This can include, for example, converting at least a portion of the observed depth data from the observer's perspective to at least one of the plurality of different light source's perspectives, before comparing the observed depth data with the source depth data. For fixed light sources and/or observer a precalculated matrix transformation lookup table can be used.

In accordance with other embodiments of the present invention, the above method can also be used to simulate dynamically changing light sources, interrupted light beams, reflected light beams, and/or projected light images, such as, for example, motion picture, video, animation, and computer graphics images. This can be accomplished, for example, by having at least a portion of the source color data being selectively controlled source color data, which can be changed over a period of time.

An arrangement that is configured to render shadows in a simulated multi-dimensional scene is also provided to meet the above stated needs and others, in accordance with certain further embodiments of the present invention. The arrangement includes a display screen configured to display image data, memory for storing data, such as, observer data, lighting data, light accumulation data, and frame data. At least one processor is coupled to the memory and the display screen and operatively configured to compare, for each of the plurality of light sources, observer data with lighting data to determine if a modeled point within the scene is illuminated by the light source and, if so, to store light image data in a light accumulation buffer, which can then be combined with observer data, and stored in the frame buffer for display via the display screen.

In accordance with still further embodiments of the present invention a method for simulating light falling on a modeled object in a computer generated multi-dimensional graphics simulation is provided. This method includes rendering a camera view of an object to produce a camera depth array and a corresponding camera image array, rendering at least one light view of the object to produce a light depth array and a corresponding light image array, and transforming camera depth data to the light view to produce a transformed camera array. The method further includes, for each data value therein, comparing the light depth array to the transformed camera array to determine if the data value in the light depth array is closer to the simulated light, and if so, adding a corresponding data value from the light image array to a light accumulation array, and then for each data value therein, multiplying the camera image array by a corresponding data value from the light accumulation array to produce a lighted camera image array.

The improved methods and arrangements of the present invention can be implemented in hardware and/or software. Thus, in accordance with certain embodiments of the present invention, a computer-readable medium is provided. A computer readable medium, by way of example, can include any tangible apparatus suitable for conveying or otherwise carrying at least one set of computer instructions. This can include a removable media associated with a computer system or a data communications link or network over which computer implemented instructions and/or data are carried, for example.

Thus, in accordance with certain embodiments of the present invention, such computer instructions are configured to cause a computer to operatively simulate light falling on a modeled object in a computer generated multi-dimensional graphics simulation by performing the following operations: 1) rendering an observer view; 2)rendering a source view; 3) transforming observed depth values to the source view; 4) modifying at least one image accumulation value with one of the observed image values if the corresponding transformed observer value is equal to a comparable one of the source depth values; 5) multiplying the one of the observed image values by the at least one image accumulation value to produce at least one pixel value; and 6) displaying the pixel value on a computer screen. In certain embodiments, following operation 4), operations 2) through 4) are repeated for each additional source.

In accordance with yet other embodiments of the present invention, there is provided a computer-readable medium carrying at least one set of computer instructions configured to cause at least one processor within a computer system to operatively render simulated shadows in a multi-dimensional simulated scene by performing the steps of providing observer data, providing lighting data, comparing observer data with lighting data to determine if a modeled point within the scene is illuminated by the light source, storing at least a portion of the light image data associated with the point and the light source in a light accumulation buffer, combining at least a portion of the light accumulation buffer with the observer data, and displaying resulting image data to a computer screen.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and arrangements of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

FIG. **1** is a block diagram depicting a computer system that is configured to generate and display interactive 3D graphics, in accordance with certain embodiments of the present invention;

FIG. **2** is a block diagram depicting an exemplary 3D graphics scene that can be rendered by a computer system as in FIG. **1**, in accordance with certain embodiments of the present invention;

FIG. **3** is a block diagram depicting exemplary arrangements of modeling data as used to render shadows, for example, using the computer system in FIG. **1**, in accordance with certain embodiments of the present invention;

FIG. **4** is an exemplary flow-chart depicting an improved shadow rendering process, for use in a computer system, for example, as in FIG. **1**, in accordance with certain embodiments of the present invention;

FIG. **5** is an exemplary flow-chart depicting further enhancements to the improved shadow rendering process in FIG. **4**, in accordance with certain further embodiments of the present invention;

FIG. **6** is an exemplary flow-chart depicting further enhancements to the process in FIG. **5**, in accordance with still further embodiments of the present invention; and

FIGS. **7**A–D are photocopies of exemplary computer screen print-outs depicting an exemplary 3D scene and related rendered depth and image data from an interactive real time graphics rendering application, in accordance with certain embodiments of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram depicting a computer system or like device, **40**, that is configured to generate and display interactive 3D graphics, in accordance with certain embodiments of the present invention. Computer system **40** includes at least one processor **42** that is configured to operate in accordance with at least one computer application **44** having computer instructions therein. Processor **42** can include at least one microprocessor or central processing unit (CPU), math co-processors, input/output processors, memory access processors, local memory cache, graphics accelerator processors, etc. A bus **46** is connected to processor **42** and configured to carry data and/or control signals thereto and therefrom. Bus **46** includes one or more buses, and can also include additional communication chip sets, interfaces, gateways, and/or networks.

A primary memory **48**, including at least one frame buffer **50**, is connected to bus **46** and configured to store data and to be accessed by at least processor **42** via bus **46**. Primary memory **48** can also include a plurality of additional memory partitions, buffers, and/or data bases **51**. Primary memory **48** typically includes random access memory (RAM) or the like. A secondary memory **52** is connected to bus **46** and configured to store data and to be accessed by at least processor **42** via bus **46**. Secondary memory **52** can include additional memory and/or a data storage device, such as, for example, a hard disk drive, removable-disk drive, a CD-ROM drive, a DVD-ROM drive, a tape drive, a server, and/or the like. A removable computer-readable media **53** is shown for use with certain types of secondary memory **52**. Media **53** can be, for example, an optical disc (e.g., CD, DVD, etc.), a magnetic disk, a data cartridge, a magnetic tape, or a similar medium configured to store data.

At least one user input device **54** is connected to bus **46** and configured to allow a user to input commands to processor **42** via bus **46**. By way of example, input device **54** can include a keyboard, a mouse, a trackball, a game input, a joy stick, a pen and tablet, a pointing device, a touch screen, a voice recognition device, or other similar devices. At least one output device **56** is connected to bus **46** and configured to display or otherwise output data from processor **42** to the user. For example, output device **56** can include a CRT display, a flat panel display, a LCD display, a plasma display, a television, a projected display, a printer, an imager, etc.

FIG. **2** is a block diagram depicting an exemplary 3D graphics scene **10** that can be rendered by computer system **40** of FIG. **1**. Scene **10** includes at least one 3D object **12** that is arranged within a defined space (e.g., background or backdrop). 3D object **12** is represented by spacial data, for example, a plurality of polygons. When viewed from camera perspective **14**, certain portions of scene **10** will be visible within the field-of-view (fov) associated with the camera and the camera's position and orientation with respect to scene **10**. Camera **14** is typically modeled as being responsive to visible light from scene **10**. As such, scene **10** is illuminated, for example, by one or more light sources, such as, a first light source **16** (#1) and a second light source **18** (#2). Light source #1, in this example, is a uni-directional light source having a particular position, orientation and constrained field-of-view. Light source #2 is, in this example, a multi-directional light source having a particular position, orientation and non-constrained field-of-view. Light sources #1 and #2 are modeled as emitting one or more frequencies of visible light, at an initial intensity (color), onto scene **10**.

A world space coordinate system **20**, for example, having an arbitrary origin and x, y, and z coordinates extending therefrom, is employed to define the spacial relationship between 3D object **10**, light sources **16** and **18**, and camera **14**. Known matrix algebra techniques are used to convert or transform between world space coordinate system **20** and the unique coordinates from the perspectives of light source **16**, light source **18**, and camera **14**. Such techniques are described, for example, in the text by Foley et al.

With this in mind, FIG. **3** is a block diagram depicting exemplary arrangements of modeling data as used to render lighting and shadows, in accordance with certain embodiments of the present invention. For convenience, the various rendered data in FIG. **3** is illustrated as being logically stored in a plurality of 2D matrices or data bases **50** and **51**A–G, each having an X axis and a Y axis. Preferably, and in this example, the X and Y axis correspond an exemplary output

device **56** having a screen that displays X by Y number of pixels when provided corresponding red-green-blue (RGB) pixel data values. Those skilled in the art will recognize that other conventions and/or arrangements can also be used for storing and manipulating the data.

For camera **14**, a camera image **51**A is rendered of scene **10**. Camera image **51**A includes RGB pixel data values from scene **10** for X by Y number of pixels (or pixel groups). An exemplary pixel **60** having camera coordinates SP_x and SP_y is depicted. Associated with camera image **51**A is camera depth **51**B. Camera depth **51**B is a Z-buffer containing depth information for each of the X by Y number of pixels in camera image **51**A. The depth image is used during rendering to correctly determine the ordering of 3D objects within scene **10**, from the camera's perspective. The use of Z-buffers is well known, for example, see Foley et al.

For light source #1, a light image **51**C is rendered of scene **10**. Light image **51**C includes RGB pixel data values for the light emitted, for X by Y number of pixels. For example, the data in light image **51**C can represent the intensity, color, and/or pattern of light emitted by light source #1. An exemplary pixel **60'**, which corresponds to pixel **60** in camera image **51**A, is depicted following transformation as having light source #1 coordinates L_1P_x and L_1P_y. Associated with light image **51**C is light depth **51**D. Light depth **51**D is a Z-buffer containing depth information for each of the X by Y number of pixels (or groups of pixels) in light image **51**C. The depth image is used during rendering to correctly determine the ordering of 3D objects within scene **10**, from light source #1's perspective.

Similarly, for light source #2, a light image **51**E is rendered of scene **10**. Light image **51**E includes RGB pixel data values for the light emitted, for X by Y number of pixels (or groups of pixels). For example, the data in light image **51**E can represent the intensity, color, and/or pattern of light emitted by light source #2. An exemplary pixel **60"**, which corresponds to pixel **60** in camera image **51**A, is depicted following transformation as having light source #2 coordinates L_2P_x and L_2P_y. Associated with light image **51**E is light depth **51**F. Light depth **51**F is a Z-buffer containing depth information for each of the X by Y number of pixels in light image **51**E. The depth image is used during rendering to correctly determine the ordering of 3D objects within scene **10**, from light source #2's perspective.

A light accumulation buffer **51**G is also depicted as having pixel data values for X by Y number of pixels (or groups of pixels), as in camera image **51**A and camera depth **51**B. Light accumulation buffer **51**G includes RGB pixel data for the accumulated light falling on a pixel (or groups of pixels) from light sources #1 and #2. As discussed below, by using light accumulation buffer **51**G, a more realistic shadow rendering can occur, because pixels are accumulatively lighted, rather than accumulatively darkened as in past interactive real time shadow rendering algorithms.

Frame buffer **50** is also depicted as having pixel data values for X by Y number of pixels, as in camera image **51**A, camera depth **51**B, and light accumulation buffer **51**G. Frame buffer **50** includes RGB data of the final rendered 2D image of scene **10**. The data in frame buffer **50** is provided to output device **56** for display to the user. Those skilled in the art will recognize that a plurality of frame buffers can be employed to allow for additional buffering of frames.

A first transformation table (#1) **51**H is also depicted in FIG. **3**. Transformation table #1, is used, in accordance with certain embodiments of the invention to provide for rapid transformation of pixels between camera coordinates and light source #1 coordinates. Transformation table #1 includes X times Y number of entries (locations), preferably arranged to directly corresponding to the sequential memory addresses of the pixel data values in camera image **51**A. When light source #1 and camera **14** each have fixed positions with respect to one another and/or scene **10**, transformation table #1 can be precalculated and populated with data using known matrix algebra relationships between the world space coordinate system **20** and the light source #1 and camera **14** perspectives. Thus, the resulting transformation table #1 can be used to quickly determine which, if any, of pixels **60'** (light image) correspond to a specific pixel **60** (camera image).

Similarly a second transformation table (#**2**) **51**I is further depicted in FIG. **3**. Transformation table #2, is used, in accordance with certain embodiments of the invention to provide for rapid transformation of pixels between camera coordinates and light source #2 coordinates. Transformation table #2 includes X times Y number of entries (locations), preferably arranged to directly corresponding to the sequential memory addresses of the pixel data values in camera image **51**A. When light source #2 and camera **14** each have fixed positions, transformation table #2 can be precalculated and populated with data using known matrix algebra relationships between the world space coordinate system **20** and the light source #2 and camera **14** perspectives. Thus, the resulting transformation table #1 can be used to quickly determine which, if any, of pixels **60"** (light image) correspond to a specific pixel **60** (camera image).

By using transformation tables **51**H–I, and precalculating the data therein, a substantial amount of processing time is saved when compared to calculating the same data "on-the-fly". This additional cost savings can be especially critical for interactive 3D graphic applications designed to operate on slower, lower-end, and/or older computer systems.

Reference is now made to FIG. **4**, which depicts an exemplary flow-chart for an improved shadow rendering process **100**, in accordance with certain embodiments of the present invention. Process **100** can be implemented, for example, in computer system **40** to render lighting and shadows for scene **10**. In step **102**, the camera's view is rendered using conventional methods, thereby producing camera image **51**A and camera depth **51**B. In step **104**, the view from a light source is rendered. For example, in step **104**, rendering the view from light source #1 produces light #1 image **51**C and light #1 depth **51**D.

Next, in step **106**, a pixel **60** in camera image **51**A is transformed or is otherwise used to determine a corresponding pixel **60'** in light #1 image **51**C (and light #1 depth **51**D). The transformation calculations needed to move between coordinates in step **106** can be precalculated and stored, for example, in transformation table #1 provided that camera **14** and light source #**1** are fixed with respect to scene **10**. Alternatively, such transformation calculations can be conducted on-the-fly provided adequate processing capability. If either camera **14** or light source #1 are not fixed with respect to scene **10**, then the transformation calculations can be conducted on-the-fly (i.e., in real-time between frames).

In step **108**, if the transformed pixel identified in step **106** is illuminated by the light source, then the corresponding pixel data value in the light image is added to the light accumulation buffer **51**G. For example, considering pixel **60'**, from the Z-value associated with pixel **60'** (as identified in light #1 depth **51**D) it can be determined if pixel **60'** is lighted by, or shaded from, light source #1. If pixel **60'** is lighted, then the corresponding (RGB) pixel data value from

light #1 image **51**C is added to light accumulation buffer **51**G. If pixel **60'** is not-lighted (i.e., is shaded), then no change is made to light accumulation buffer **51**G.

Steps **106** and **108** are repeated for each of the pixels in camera image **51**A, as depicted by the iteration provided by step **110**. After all of the pixels in camera image **51**A have been processed in steps **106**–**110**, then, according to step **112**, the process is repeated for each additional light source. Step **112** leads back to step **104**, wherein the next light source view is rendered. For example, steps **104**–**110** can be repeated again for light source #2 (or #N light sources). This iterative process allows for each of the pixel data values within light accumulation buffer **51**G to be incrementally increased in a manner that matches the cumulative light cast by the multiple light sources on each pixel.

After each of the light sources has been processed in accord with steps **104** through **112**, then in step **114**, a pixel data value from camera image **51**A is multiplied by a corresponding pixel data value from light accumulation buffer **51**G and the results are stored in camera image **51**A. Step **114** is repeated for each of the pixels in camera image **51**A, as depicted by iterative step **116**. Then, in step **118**, a resulting camera image **51**A is further rendered in accord with other processes, as needed, and eventually stored in frame buffer **50** and displayed as a frame of data.

Process **100**, therefore, in accordance with certain aspects of the present invention, provides realistic lighting and shadow rendering while also being computationally efficient. Process **100** can be adapted for a plurality of light sources, either fixed or moving, and for changing camera views. By way of example, the following exemplary pseudocode can be implemented in either hardware of software to provide for process **100**:

```
RENDER EACH VIEW (PARTIAL IF THE LIGHT IS STATIONARY)
CLEAR ACCUM BUFFER
FOR EACH LIGHT SOURCE . . .
  FOR EACH PIXEL IN CAMERA IMAGE SP_X, SP_Y . . .
    TRANSFORM EACH SP TO A LP {LIGHT PIXEL} USING
    EITHER:
      TRANSFORM LOOK-UP TABLE,
        OR
      MATRIX TRANSFORMATION CALCULATION
      IF LP_Z < LIGHT DEPTH (LP_X, LP_Y) THEN
        ACCUM (SP_X, SP_Y) += LIGHT IMAGE (LP_X, LP_Y)
FOR EACH PIXEL IN CAMERA IMAGE . . .
    CAMERA IMAGE (SP_X, SP_Y) *= ACCUM (SP_Y, SP_Y)
```

The flow-chart in FIG. **5** depicts an exemplary process **120** that can be included in step **106**. Process **120** includes step **122**, wherein an applicable transformation table is used to determine the transformation from camera to light source viewpoints when the camera and light source are fixed with respect to scene **10**. Otherwise, in step **124**, if the camera or light source are not fixed then a matrix transformation algorithm is used.

An exemplary process **130** is depicted in the flow-chart of FIG. **6**. Process **130** can be used to precalculate transform tables and/or included in step **124** calculate the transform on-the-fly. In step **132**, a transformation is made from world space coordinate system **20** to camera coordinates. Next, in step **134**, a transformation is made from camera coordinates to light source coordinates. These types of transformation processes, which are preferably completed using standard matrix algebra, are well known to those skilled in the art (see, e.g., Foley et al. text). In step **136**, the resulting transformation data (camera to light source) is provided in a translation table per step **138**, or returned to the shadow rendering process per step **140**.

FIGS. **7**A–D depict actual computer screen shots for an exemplary 3D scene of an interactive real time graphics rendering application, having an improved shadow rendering capability as described above and configured for a PC, in accordance with certain embodiments of the present invention. The application that generated the images depicted in FIGS. **7**A–D is a computer-based interactive adventure game. In the exemplary scenes, the camera and two light sources are each fixed with respect to the scene. The frame in FIG. **7**A is a monochrome photocopy of the colored rendered scene. The frame of FIG. **7**A is shown inverted in FIG. **7**B to further highlight the shadowing rendered in the scene. FIG. **7**C is a essentially a "behind the scenes" view of various image buffers that are used to generate the image of FIG. **7**A. FIG. **7**D is the inverted image of FIG. **7**C.

Reference will first be made to the image in FIG. **7**A, with reference numerals being added to the inverted image of FIG. **7**B and/or the fully lighted image of FIGS. **7**C–D. In FIG. **7**A there is depicted a portion of a room **200** having texture mapped walls **202**A–D, floor **204**, and ceiling **205**. One of the walls **202**B has a large mirror **203**, in which is shown the reflection from another wall **202**D having several pictures hanging thereon. Additional 3D objects within the room include torches **206**A and **206**B mounted on side walls, **202**A and **202**C, respectively. A man **208** is shown standing on floor **204** and in front of the mirrored wall **202**B. Light is being reflected onto a portion of the mirrored wall **202**B, the floor **204**, the man **208**, and on the wall **202**D having pictures hanging thereon. The man **208** casts a shadow **210** onto a portion of the floor **204** and the mirrored wall **202**B.

The frame in FIG. **7**A, and in particular, the lighting rendered in the scene is demonstrated by the additional images in FIG. **7**C. Room **200'** is depicted in full light in FIG. **7**C. From this image of room **200'**, one can understand the configuration of the modeled 3D world. Refer to the inverted image of FIG. **7**D, as required, to identify a specific reference. FIG. **7**C also includes four other images that are used to render the lighting and shadows in room **200'**.

There are two light sources that are not visible within room **200'**. These light sources are used to simulate the light emitted by simulated torches **206**A and **206**B. These light sources, which are not shown in FIG. **7**C, are directional light sources having fixed positions with respect to room **200**. Image **220** represents the light depth data for the first light, which has a circular field of view (or aperture) and is positioned to shine light on a portion of floor **204** and mirrored wall **202**B. The information depicted in image **220** corresponds to depth, for example, as stored in a Z-buffer associated with this particular light source. Within depth image **220**, as depicted in FIG. **7**C, the closer a pixel is to the light source, the darker its image. Thus, for example, the man **208** in FIG. **7**C is closest to the light source and as such is rendered the darkest shade. Conversely, the interface (corner) of mirrored wall **202**B and floor **204** is the farthest away from the light source and as such is rendered the lightest shade. This is just one convention, obviously the convention could be reversed in other systems. Note, that the image **220** in FIG. **7**D is inverted and thus so to is the convention.

Also associated with the first light source is a light image **224**. In this example, light image **224** includes a graduated pattern of intensity that is highest near the center and lowest near the edges. In this example, light image **224** is essen-

tially a light filter based on a cosine function. It is intended, however, that the RGB pixel data values in a light image can include any pattern of RGB data, including static and dynamically changing patterns. For example, in accordance with certain embodiments of the present invention, a light image can include a dynamically changing graphical image. This can be used to simulate light that is reflected from changing surfaces, such as, for example, the light reflected from a rippling body of water. By dynamically changing the light image using a recorded or simulated image of such a body of water, the light source will essentially paint the scene with a rippling light. Taken a further step, the light image can include an animation, motion picture or similar video image that is projected, not unlike a movie projector, on to the various surfaces of the scene. Indeed, this can be used to model a movie projector, wherein 3D objects, such as man **208** can walk in front of the projected light image and have portions of the projected image fall on his body.

With regard to man **208** as depicted in depth image **220**, the depth image **220** has been further processed in this example to include data relating to the depth of man **208**. This can be accomplished, for example, by comparing previous frames and completing new transform calculations for pixels that have changed and that are in the depth image for the light source. Thus, for example, from the previous frame, man **208** may have moved slightly (e.g., in response to inputs from the user). A portion of the pixels are identified as having changed from the previous frame. The portion of the pixels that changed are then transformed and processed to generate new modified light depth data **228**. In this manner, only those portions of the scene that change need to be reprocessed.

For the second light source, a depth image **222** and light image **226** are also provided. Depth image **222** demonstrates that the second light source is positioned facing wall **202**D and casting light on a portion of floor **204** and wall **202**D. Light image **226** is similar to light image **224**. Note that depth image **222** does not include man **208** or any other moving 3D object at this time. Thus, depth image **222** need not be updated at this time.

The various images in FIG. **7**C are processed in accordance with process **100**. A light accumulation buffer and subsequent frame buffer are created by combining data from the image of room **200'**, and light images **224** and **226**, in accordance with the data in depth images **220** and **222**. The resulting frame buffer is that of FIG. **7**A, which clearly shows that man **208** casts a single shadow **210** as a result of the first light. Additionally, the accumulated light on mirrored wall **202**B and **202**D are shown.

In accordance with still further embodiments of the present invention, if camera **14** is required to periodically change position with respect to scene **10**, for example, during an interactive simulation, then process **120** is repeated as necessary to recalculate and update the applicable transform tables, or to generate different, additional transform tables, based on the new camera position. If the camera is continually moving with respect to scene **10**, then rather than manipulating and accumulating light based on pixels, process **100** is adapted to manipulate groups of pixels and/or polygons. This allows for a more granular approach, in which a light image can be rendered for each polygon, and light accumulation buffers can be used to accumulate light intensities from the various light sources for each polygon, rather than for each screen pixel. As such, a plurality of light images can be precomputed, one for each of the polygons (or for groups of polygons), for each of the fixed lights.

Although several preferred embodiments of the methods and arrangements of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

What is claimed is:

1. A shadow rendering method, the method comprising the steps of:

providing observer data of a simulated multi-dimensional scene;

providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;

for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in a light accumulation buffer; and then

combining at least a portion of said light accumulation buffer with said observer data; and

outputting resulting image data.

2. The method as recited in claim **1**, wherein said observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

3. The method as recited in claim **1**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel, such that said observed color data includes an observed red-green-blue value for said pixel and said observed depth data includes an observed z-buffer value for said pixel.

4. The method as recited in claim **1**, wherein said lighting data includes source color data associated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives.

5. The method as recited in claim **4**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel, such that said source color data includes a source red-green-blue value for said pixel and said source depth data includes a source z-buffer value for said pixel.

6. The method as recited in claim **4**, wherein the step of comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source further includes comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source.

7. The method as recited in claim **6**, wherein the step of comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source further includes converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives, before comparing said observed depth data with said source depth data.

8. The method as recited in claim **7**, wherein the step of converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives further

includes using a precalculated matrix transformation look-up table for at least one of said plurality of light sources, when said light source has a fixed perspective of said scene.

9. The method as recited in claim **1**, wherein at least a portion of said source color data is selectively controlled source color data that can be changed over a period of time during which at least the step of outputting the resulting image data is repeated a plurality of times.

10. The method as recited in claim **9**, wherein said controlled source color data includes data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

11. An arrangement configured to render shadows in a simulated multi-dimensional scene, the arrangement comprising:

an output to a display screen configured to display image data;

memory for storing data including observer data associated with a simulated multi-dimensional scene, and lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data, said memory further including a light accumulation buffer portion and a frame buffer portion;

at least one processor coupled to said memory and said output and operatively configured to, for each of said plurality of light sources, compare at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in said light accumulation buffer, then combining at least a portion of said light accumulation buffer with said observer data, and storing resulting image data in said frame buffer, and outputting at least a portion of said image data in said frame buffer via said output.

12. The arrangement as recited in claim **11**, wherein said observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

13. The arrangement as recited in claim **12**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said display screen, such that said observed color data includes an observed red-green-blue value for said pixel and said observed depth data includes a observed z-buffer value for said pixel.

14. The arrangement as recited in claim **12**, wherein said lighting data includes source color data associated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives.

15. The arrangement as recited in claim **14**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel, such that said source color data includes a source red-green-blue value for said pixel and said source depth data includes a source z-buffer value for said pixel.

16. The arrangement as recited in claim **14**, wherein said processor is further configured to compare at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source.

17. The arrangement as recited in claim **16**, wherein said processor is further configured to convert at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives, before comparing said observed depth data with said source depth data.

18. The arrangement as recited in claim **17**, wherein said memory further includes at least one precalculated matrix transformation table associated with at least one of said plurality of light sources, and said processor is further configured to use said precalculated matrix transformation look-up table when said light source is simulated as having a fixed perspective of said scene.

19. The arrangement as recited in claim **14**, wherein said processor is further configured to selectively control at least a portion of said source color data over a period of time.

20. The arrangement as recited in claim **19**, wherein said controlled source color data includes data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

21. A computer-readable medium carrying at least one set of computer instructions configured to cause a computer to operatively simulate light falling on a modeled object in a computer generated multi-dimensional graphics simulation by performing operations comprising:

a) rendering an observer view of at least a portion of a spatially modeled object as a plurality of observed depth values and observed image values;

b) rendering a source view of at least a portion of said modeled object as a plurality of source depth values and a plurality of source image values;

c) transforming at least a portion of said observed depth values to said source view;

d) modifying at least one image accumulation value with one of said observed image values if said corresponding transformed observer value is equal to a comparable one of said source depth values;

e) multiplying said one of said observed image values by said at least one image accumulation value to produce at least one pixel value; and

f) output said pixel value to a computer screen.

22. The computer-readable medium as recited in claim **21**, further configured to cause tcomputer to perform the further step of:

g) following step d), repeating steps b) through d) for at least one additional source view.

23. The computer-readable medium as recited in claim **22**, further configured to cause the computer to perform the further steps of:

h) repeating steps a) through g) a frame rate; and

wherein step f) further includes sequentially outputting a plurality of pixels as frames of data to said computer screen at said frame rate, and said step of rendering said source view further includes changing at least one of said source image values between said subsequent frames of data.

24. The computer-readable medium as recited in claim **23** wherein at least a portion of said source image values represent color data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

25. The computer-readable medium as recited in claim **23**, wherein step c) further includes transforming at least a portion of said observed depth values from an observer coordinate system to a corresponding source coordinate system.

26. The computer-readable medium as recited in claim **25**, wherein the step of transforming at least a portion of said

observed depth values from an observer coordinate system to a corresponding source coordinate system further includes using a precalculated transformation table to transform directly from said observer coordinate system to said corresponding source coordinate system.

27. A computer-readable medium carrying at least one set of computer instructions configured to cause at least one processor to operatively render simulated shadows in a multi-dimensional simulated scene by performing the steps of:

providing observer data of a simulated multi-dimensional scene;

providing lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;

for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source in a light accumulation buffer; and then

combining at least a portion of said light accumulation buffer with said observer data; and

outputting resulting image data.

28. The computer-readable medium as recited in claim **27**, wherein said observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

29. The computer-readable medium as recited in claim **28**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel, such that said observed color data includes an observed red-green-blue value for said pixel and said observed depth data includes a observed z-buffer value for said pixel.

30. The computer-readable medium as recited in claim **28**, wherein said lighting data includes source color data associated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives.

31. The computer-readable medium as recited in claim **28**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel, such that said source color data includes a source red-green-blue value for said pixel and said source depth data includes a source z-buffer value for said pixel.

32. The computer-readable medium as recited in claim **30**, wherein the step of comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source further includes comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source.

33. The computer-readable medium as recited in claim **32**, wherein the step of comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source further includes converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives, before comparing said observed depth data with said source depth data.

34. The computer-readable medium as recited in claim **33**, wherein the step of converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives further includes using a precalculated matrix transformation look-up table for at least one of said plurality of light sources, when said light source has a fixed perspective of said scene.

35. The computer-readable medium as recited in claim **30**, wherein at least a portion of said source color data is selectively controlled source color data that can be changed over a period of time during which at least the step of outputting the resulting image data to a display device is repeated a plurality of times.

36. The computer-readable medium as recited in claim **35**, wherein said controlled source color data includes data selected from a set comprising motion picture data, video data, animation data, and computer graphics data.

37. A computer circuit for processing computer graphics data coupled to at least one processor to operatively render simulated shadows in a multi-dimensional simulated scene by performing steps comprising:

a) receiving observer data of a simulated multi-dimensional scene;

b) receiving lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;

c) for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source;

d) combining at least a portion of said stored light image data with said observer data; and

e) transmitting resulting image data to be displayed on a computer screen.

38. The computer circuit recited in claim **37**, wherein said observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

39. The computer circuit recited in claim **38**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel, such that said observed color data includes an observed red-green-blue value for said pixel and said observed depth data includes an observed z-buffer value for said pixel.

40. The computer circuit recited in claim **38**, wherein said lighting data includes source color data associated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives.

41. The computer circuit recited in claim **38**, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said computer screen, such that said source color data includes a source red-green-blue value for said pixel and said source depth data includes a source z-buffer value for said pixel.

42. The computer circuit recited in claim **40**, where in the step of comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source further includes comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source.

43. The computer circuit recited in claim 42, where in the step of comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source further includes converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives, before comparing said observed depth data with said source depth data.

44. The computer circuit recited in claim 43, wherein the step of converting at least a portion of said observed dept data from said observer's perspective to at least one of said plurality of different light source's perspectives further includes using a look-up table containing predetermined transformation values for at least one of said plurality of light sources, when said light source has a fixed perspective of said scene.

45. The computer circuit recited in claim 40, wherein at least a portion of said source color data is selectively controlled source color data that can be changed over a period of time during which at least the step of transmitting the resulting image data to said computer screen is repeated a plurality of times.

46. The computer circuit recited in claim 45, wherein said controlled source color data includes data selected from stored motion picture data.

47. The computer circuit recited in claim 45, wherein said controlled source color data includes data selected from stored computer animation data.

48. The computer circuit recited in claim 45, wherein said controlled source color data includes data selected from stored video data.

49. The computer circuit recited in claim 45, wherein said controlled source color data includes data selected from stored computer graphics sequence data.

50. A computer circuit for processing computer graphics data coupled to a computer system to operatively render simulated shadows in a multi-dimensional simulated scene by performing steps comprising:

a) receiving observer data of a simulated multi-dimensional scene;

b) receiving lighting data associated with a plurality of simulated light sources arranged to illuminate said scene, said lighting data including light image data;

c) for each of said plurality of light sources, comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source and storing at least a portion of said light image data associated with said point and said light source;

d) combining at least a portion of said light image data with said observer data; and

e) transmitting resulting image data for display on a computer screen.

51. The computer circuit recited in claim 50, wherein said observer data includes observed color data and observed depth data associated with a plurality of modeled polygons within said scene as rendered from an observer's perspective.

52. The computer circuit recited in claim 51, wherein said plurality of modeled polygons within said scene are associated with at least one pixel, such that said observed color data includes an observed red-green-blue value for said pixel and said observed depth data includes an observed z-buffer value for said pixel.

53. The computer circuit recited in claim 51, wherein said lighting data includes source color data associated with at least one of said light sources and source depth data associated with said plurality of modeled polygons within said scene as rendered from a plurality of different light source's perspectives.

54. The computer circuit recited in claim 51, wherein said plurality of modeled polygons within said scene are associated with at least one pixel on said computer screen, such that said source color data includes a source red-green-blue value for said pixel and said source depth data includes a source z-buffer value for said pixel.

55. The computer circuit recited in claim 53, where in the step of comparing at least a portion of said observer data with at least a portion of said lighting data to determine if a modeled point within said scene is illuminated by said light source further includes comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source.

56. The computer circuit recited in claim 55, where in the step of comparing at least a portion of said observed depth data with at least a portion of said source depth data to determine if said modeled point is illuminated by said light source further includes converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives, before comparing said observed depth data with said source depth data.

57. The computer circuit recited in claim 56, wherein the step of converting at least a portion of said observed depth data from said observer's perspective to at least one of said plurality of different light source's perspectives further includes using a look-up table containing predetermined transformation values for at least one of said plurality of light sources, when said light source has a fixed perspective of said scene.

58. The computer circuit recited in claim 53, wherein at least a portion of said source color data is selectively controlled source color data that can be changed over a period of time during which at least the step of transmitting the resulting image data to said computer screen is repeated a plurality of times.

59. The computer circuit recited in claim 58, wherein said controlled source color data includes data selected from stored motion picture data.

60. The computer circuit recited in claim 58, wherein said controlled source color data includes data selected from stored computer animation data.

61. The computer circuit recited in claim 58, wherein said controlled source color data includes data selected from stored video data.

62. The computer circuit recited in claim 58, wherein said controlled source color data includes data selected from stored computer graphics sequence data.

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